A

TREATISE

ON THE

VARIOUS KINDS

OF

PERMANENTLY ELASTIC

FLUIDS,

OR

GASES.

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PREFACE.

THE following sheets are intended as an *Appendix* to the second English Edition of *M. Macquer's Dictionary of Chemistry*, instead of the Article, *Fixable Air*, which was added to the former Edition. This Subject has been lately so successfully cultivated, since the writing of that Article, that a revisal and large additions were necessary: but these not having been finished in time for insertion into their proper alphabetical place, when the second edition of the Dictionary was printing, and being besides too large for an additional article, the following treatise is subjoined as an Appendix.

The name of the subject is changed from those commonly employed, viz. *Fixable*, *Fixed*, or *Factitious Air*, to that of *Gas*: and perhaps this liberty may be thought to require some apology. The impropriety of applying the word *Air* to all permanently elastic Fluids is evident, from considering that this word has been immemorially appropriated to express only

one of these, namely, the Atmospherical Fluid, and that the other elastic fluids are very different in most of their properties, although they have been frequently confounded with it. The impropriety could not be greater, if all *liquids* were confounded under the name of *Water*. And probably the first discoverer of other liquids committed this impropriety. Oil he might call inflammable water; and vinegar, acid water. How much the acquisition of Science is obstructed by impropriety of terms, is well known: and therefore, although those Authors, to whom the philosophical World is obliged for the advancement of their knowledge on this subject, have generally employed the terms already in use, and to which they themselves have been familiarised; yet it is scarcely pardonable in a systematic Author, who collects the knowledge already attained, and who writes chiefly for learners, to use expressions avowedly improper, and capable of misleading the judgment. But the liberty which I take will appear more allowable, when it is considered that the word *Gas* is not newly invented, but has been applied to denote these fluids by *Van Helmont*, who first described clearly most of the kinds yet known. Neither is the Etymology of the word exceptionable, as it signifies that bubbling appearance which is exhibited when these elastic fluids are disengaged from any liquid. The number also of the Fluids first describ-

described and distinguished by this most ingenious Author is so considerable, as to give to him the best right of imposing a name.

It has indeed been lately suggested that *Van Helmont* did not distinguish permanently elastic fluids from condensable vapours and exhalations. But I think a very different opinion will be formed upon examining his works, in which the following propositions are maintained.

1. Certain fluids (to which he first gave the name of *Gas*) escape from various substances, and in various operations. See an *enumeration* of the principal gases mentioned by Van Helmont, in a note subjoined to page 3d of the following Treatise.

2. These Gases *differ from vapour*, which consists of minute particles of water or other liquids, and which may be again reduced to the same bodies whence it was exhaled; whereas gases are incondensable [*quod in corpus non cogi potest visibile*; and *incoagulabile.*] *De flatibus* § 33. *Paradox. secund.* § 9. *Aura vitalis.* * Thus he

* He says indeed that the vapour of water when raised into the upper regions of the air may, by cold, be converted into gas; and that gas may in length of time lose its peculiar nature of gas and be converted into water. But this opinion is only a consequence of his general Theory, that Water and Air are the two elements from which all things are formed. *Gas aquæ* § 13. *Complex. atq. Mistion. elem. figm.* § 38.

he obſerves, that the vapour raiſed from ſpirit of nitre by diſtillation, is nothing but that ſpirit rarefied, which paſſes wholly into the receiver, without any gas: but that upon adding any metal ſoluble in that acid, a Gas is formed which is capable of burſting the ſtrongeſt veſſels. *De flatibus* § 67. This gas is evidently that which is now ſo well known by the name of *Nitrous Air*, and which we have deſcribed in chap. 10. under the name of *Nitrous Gas.*

3. The Gaſes *differ alſo from atmoſpherical air* (which however he calls ſometimes *gas ventoſum)* and are not to be conſidered as air which had been pent up in the interſtices of bodies, *Complexion. atq. Miſtion. elem. figm.* § 19.

4. Gaſes do not exiſt, as ſuch, in the bodies, whence they are expelled; but are *new productions* formed, by the action of fermentation, fire, and other cauſes, from the deſtruction of bodies, and by means of new combinations. Thus he obſerves that the gas formed in the deflagration of gun-powder, did not exiſt in the nitre, ſulphur, and charcoal, but is formed by their action on each other, and mutual deſtruction. *De flatib.* § 62, 63. 67, 68. *Complexion. atq. Miſtion. elem. figm.* § 21, &c.

I believe the following Treatiſe is the firſt attempt to arrange the knowledge which we have

have acquired on this subject, the gentlemen to whom we are obliged for this knowledge, having only communicated their proper discoveries. Neither should I, at this time, when this branch of Experimental Philosophy is generally cultivated in many parts of Europe, and every day brings forth new truths, have thought of the present task, if it had not been a necessary supplement to the edition of the Dictionary of Chemistry now published. *M. Lavoisier* has indeed given an account of the progress made by the several philosophers who have advanced our knowledge on the same subjects. But his plan is very different from mine. He relates the discoveries in the order in which they occurred to their authors; thus including in one chapter all the discoveries made by one man concerning many different kinds of fluids. I relate these discoveries in the order in which they are naturally connected; thus collecting into one chapter all that is known concerning one Fluid; and at the same time assigning each discovery, concerning this Fluid, to its proper Author. *M. Lavoisier*'s work is useful and entertaining, especially to those who are already conversant on the subject, as it shews how much each person has contributed. Mine I hope will not be less useful, as it presents the Science in the order in which it may be most easily attained. But while I express my hope that it may facilitate the study of this subject to learners,

ers, and may even be agreeable to perſons already informed, by exhibiting under one view the principal diſcoveries and obſervations arranged under their proper heads, yet my aim is not to *ſatisfy* the curioſity of readers, but rather to *excite* it, ſo that they may recur to the ſame valuable originals, of which I have rather extracted the heads, than exhauſted the contents; and where they will find many Obſervations tending to confirm the principal Reſults; many Facts curious, but too detached for inſertion in the following pages; and much ingenious Speculation.

A TREATISE ON THE VARIOUS KINDS OF GAS, &c.

CHAP. I.

Definition and Enumeration of Gases.

1. MOST, perhaps all, ſubſtances, ſolid and liquid, may, by heat, more or leſs intenſe, be converted into *vapours*, that is, fluids exceedingly rare, inviſible, and highly elaſtic. Thus when water is expoſed to a heat ſufficient to raiſe the mercury in Fahrenheit's thermometer to 212°, it becomes gradually changed into ſuch a vapour; and the water thus changed, while it continues expoſed to that temperature, remains in a rare, inviſible, and elaſtic ſtate.

Several ſubſtances which were formerly thought unalterable by fire, have been lately diſcovered to be ſuſceptible of evaporation, when expoſed to a heat ſufficiently intenſe. *Diamonds* have been ſhewn by the French Academicians to be evaporable by a heat not much more intenſe than that uſed in the cupella-

 tion

tion of silver. Gold and silver are said to have been elevated by the heat of a concave mirror.†

2. Many of the substances thus volatilized, or converted into the state of vapour, by heat, may be again condensed into concrete, or palpable and visible substances, by exposing them to a heat less intense than that which was necessary to produce their evaporation. Thus when the vapour of water is exposed to some degree of heat less than 212°, it loses its great elasticity, and bulk; and is again *condensed*, that is, reduced to its original state of a liquid.

3. Several other highly elastic, invisible, rare fluids cannot, by the cold of the atmosphere, or by any degree of cold to which they have hitherto been known to be exposed, be thus condensed. Such is the *Air* which we breathe, and such are the *elastic fluids*, which escape from wine and other fermenting liquors, and from the effervescing mixtures of acids and alkalis.

These *Fluids* are called *permanently elastic*, because they cannot like those mentioned in § 2, be deprived of their elasticity by cold.‡ They are also called Gas by

† Buffon supplement, Tome 3me.

‡ The Fluids called *permanently* elastic, may be fixed, absorbed, or deprived of their elasticity, by being combined with certain substances, as water and calcareous earth. The *permanency* of their elasticity is therefore to be understood only relatively to the effects of cold, and indeed of that degree only of cold which has been hitherto applied to them; for possibly some or all of those Gases which have hitherto resisted any cold to which they have been observed to be exposed, might be condensed by some degree of cold more intense.

by *Van Helmont*, who discovered many kinds of these permanently elastic fluids.§

4. A GAS may therefore be *defined* "AN EXCEEDINGLY RARE, HIGHLY ELASTIC, INVISIBLE FLUID, NOT CONDENSIBLE BY COLD."

§ *Van Helmont* justly describes his *Gas Sylvestre* to be an invisible and incondensible Fluid, *incoercibile et quod in corpus non cogi potest visibile*. The word *Gas* is derived from the German *Gascht*, which signifies a frothy ebullition, such as accompanies the expulsion of Gas from effervescing and fermenting substances. (See *Junckeri conspectus Chem.* 1.) Mr. *Boyle*, and other English authors, who have cultivated this branch of Natural Philosophy, considering the several permanently elastic fluids which they obtained from different substances, as the atmospherical air, which they supposed to exist in a *fixed* or unelastic state in certain substances, till it was dislodged by artificial processes, or thinking that the word *Air* might be applicable to any permanently elastic fluid, have described these fluids under the names, *Factitious Air*, *Fixed* or *Fixable Air*; to which latter experimentalists have added *Inflammable Air*, *Nitrous Air*, &c. But as these names lead to an opinion, which has not been proved, nor seems probable, that the permanently elastic fluids are modifications of the atmosphere which environs our globe, to which the name *Air* has been immemorially appropriated, I follow *Van Helmont*, the discoverer of many of the known kinds of these fluids, in comprehending all that are elastic, invisible, and incondensible by cold, under the general name *Gas*, (the etymology of which is not very exceptionable) and in distinguishing the several kinds by descriptive epithets, as, *Vinous Gas*, *Nitrous Gas*, *Inflammable Gas*, &c.

Among the many Gases mentioned by *Van Helmont*, are the *Gas ventosum*, or *atmospherical Air*; the *Gas pingue*, or the Gas extricated by applying heat to inflammable substances; the *Gas Sylvestre*, or the Gas produced from fermenting, and effervescing substances; the *Gas flammeum*, or the Gas produced in the deflagration of nitre; the Gas produced in the distillation of *tartar*; the Gas produced in the burning of *charcoal*; the Gas of the *grotta del cane*, and subterranean places, as *mines*; the Gas produced by the *putrefaction* of animal bodies; the matter which produces the *plague*; the *arterial spirit of life*; and lastly, his celebrated *Archaeus*.

5. The *various kinds of Gas* hitherto discovered, *native* or produced by *art*, are enumerated below. These shall be treated successively. More kinds will probably be discovered by means of future experiments and observations; and perhaps some of these now distinguished, may be hereafter shewn to be of the same kind.

6. 1. *Atmospherical Gas*, or, *Air*.

2. *Vinous Gas*; or the Gas extricated from substances undergoing the vinous fermentation.

3. The Gases expelled from substances undergoing the *putrefactive fermentation*.

4. The Gases obtained from *animal* and *vegetable substances* by means of fire.

5. *Calcareous Gas*; or, the Gas expelled by fire, or by acids, from *calcareous* and *alkaline* substances.

6. *Gas* observed in *mines*.

7. *Gas* contained in *waters*, especially those called *mineral*.

8. *Vitriolic acid Gas*.

9. *Nitrous acid Gas*.

10. *Nitrous Gas*.

11. *Marine acid Gas*.

12. *Inflammable Gases*.

13. *Fulminating Gases*.

14. *Gas* obtained by *reviving metallic calxes*.

15. *Alkaline Gas*.

16. *Other kinds* of *Gases*.

The above enumeration of Gases is principally deduced from their origin, or effects. Our knowledge of these fluids is not yet sufficiently extensive and accurate to admit of a more perfect arrangement or classification according to their component parts.

CHAP.

CHAP. II.

On Atmospherical Gas, or Air.

7. ATmospherical *Gas*, or *common Air*, is the invisible, insipid, inodorous, pellucid, sonorous, elastic fluid that surrounds our Globe. Physical writers have treated copiously on its gravity, elasticity, and other mechanical qualities. Its *chemical* properties have been discussed at the article *Air* of the *Dictionary of Chemistry*. Here therefore some supplemental observations only shall be added, concerning its *affections* by *different substances*, and its *constitution*.

8. Air is capable of *combining with various substances*. Hence the atmosphere is replete with diverse exhalations, and with all those matters which the air can dissolve: and its properties are affected by the quantity and kind of foreign particles contained in it.

9. *Water* is one of those substances which *Air is capable of dissolving*; and accordingly more or less of this liquid is always contained in the atmosphere; as appears from the moisture imbibed by dry caustic alkali exposed to air, or by the condensation of moisture on the external surface of a vessel in which artificial cold is produced by mixture of salt and snow. Probably no part of the atmosphere is ever free from a portion of dissolved water, besides the watery particles that float *visibly*, (for water dissolved

in air is invisible) forming clouds, and fogs; all which are *mechanically* suspended in the lighter atmosphere, as gold-leaf is in water, and not *chemically* combined with the air.

Some philosophers have attributed the rise of *exhalations* to the dissolving property of air, exerted upon the moisture on the surface of the earth. But although this cause may concur, it does not solely or principally produce this phenomenon; for water is known to evaporate not only in air, but also in vacuo.

10. As water is capable of being dissolved by air, and thereby diffused through the mass of the atmosphere, so also is *air capable of being absorbed by water*, and the air thus absorbed seems to lose part of its elasticity. Thus if water be deprived by boiling of all the air or other Gas contained in it, and afterwards be exposed to the atmosphere, it will absorb some air. And if a bubble of air be admitted into an inverted bottle filled with boiled water, the whole quantity of air will be absorbed, provided the bubble of air be not larger than is requisite to saturate the quantity of water employed. ||

The quantity of air capable of being absorbed by a given quantity of water, is according to Dr. *Hales*, equal in bulk to $\frac{1}{54}$th part, and according to *Nollet*, to $\frac{1}{30}$th part of the water employed.‡

|| This absorption of air by water has been generally said to occasion no sensible encrease of the bulk of the liquid. *Muschenbrook* however observes that the air absorbed by water does add a very *little* to the bulk of the water; but that any difference it may produce in the specific gravity of the liquid is so small that it can scarcely be discovered by experiments. *Introd.* § 1481.

‡ We need not wonder that a substance so rare and elastic as air should be thus united to water, and by the union be deprived of the greatest

11. *Air*

11. *Air promotes the combuſtion of inflammable bodies*; and the air thus employed is *altered* by the operation. Thus when charcoal or other inflammable ſubſtance is burnt, the air in which this combuſtion happened, becomes poſſeſſed of properties very different from thoſe of common air.

12. *Air thus altered by burning ſubſtances becomes leſs in bulk* than it was before the alteration, as Mr. *Boyle* has obſerved. Thus, when lighted candles or other kindled ſubſtances are put under a receiver, the mouth of which is inverted and immerſed in a veſſel filled with water, they burn a little while, longer or ſhorter, according as the quantity of air is greater or leſs relatively to the quantity of ſubſtance actually in combuſtion at a time. When they have ceaſed to burn, the water

greateſt part of its elaſticity; this phenomenon being conſentaneous with the general analogy of chemical ſolutions or combinations. For in all chemical ſolutions, the integrant parts of one body are divided and ſeparated by thoſe of the other component body. Thus the particles of air are ſeparated from each other by the particles of water. But elaſticity or expanſive force cannot be conſidered as the property of any ſingle particle, for it implies two particles, at leaſt, endeavouring to recede from each other. The particles therefore of air being conſiderably disjoined from each other, and engaged with thoſe of water, may have their expanſive power ſo much weakened, that they yield to the combining power of water. The elaſticity however of air abſorbed by water is not deſtroyed, but only diminiſhed; for by the application of heat, or by removing the preſſure of the atmoſphere, the air recovers its expanſive force, and diſengages itſelf from the water. Thus *M. de Luc* obſerved, when he was making thermometers with different liquors, that theſe liquors which had been deprived by boiling of much of their contained Air or other Gas, did nevertheleſs expand gradually, and riſe many degrees in the ſtems of the thermometers, when the preſſure of the atmoſphere was removed, and that this expanſion took place long before any bubbles appeared. See *Recherches ſur la modification de l'atmoſphere.* I. 230.

water within the receiver may be ſeen to riſe higher than it was before the combuſtion, as ſoon as the included air has loſt the heat it had received from the burning ſubſtance. The greater height of the water within the receiver after than before the combuſtion ſhews that the included air preſſes with leſs force on the ſurface of the water than the external air does; and conſequently is reduced to a ſmaller ſpace than it occupied before the combuſtion.

This *diminution of the preſſure*, or of the *bulk* of the quantity of air contained in the receiver, occaſioned by the combuſtion of inflammable ſubſtances, may depend upon a *diminution of the quantity* of this elaſtic fluid by *abſorption*, or by *precipitation* of part of it, or upon a *diminution merely of its elaſticity*, while the quantity remains the ſame. Dr. *Hales* conſiders it as a diminution of the elaſticity of the contained air: but Dr. *Prieſtly* is inclined to think, that it is a diminution of the quantity of air, ſome part being precipitated; and he is induced to this opinion, from his not having been able to find any *conſiderable* alteration in the ſpecific gravity of the air in which candles or brimſtone had burnt. From ſeveral trials purpoſely made he thinks that this diminiſhed air was not heavier, but rather lighter than common air. I. 46. and 267. II. 94.

Dr. *Hales* obſerved that the *air continued to diminiſh* under the receiver ſeveral days after the extinction of the candles. This continued diminution may probably have been occaſioned by a gradual abſorption of ſome part of the air by the water in which the inverted receiver was immerſed; for Dr. *Prieſtly* remarks, that "this diminution of air by burning is not always im-"mediately apparent, till the air has paſſed ſeveral

" times

" times through water; and that when the expe-
" riment was made with veſſels ſtanding in quickſilver
" inſtead of water, the diminution was generally in-
" conſiderable till the air had paſſed through water."
p. 46.

Air altered by burning ſubſtances occaſions *a precipitation in lime water*. It appears therefore that by combuſtion ſome Gas is produced which is capable of uniting with the quicklime diſſolved in the lime-water. Whether this Gas proceeds from the combuſtible body employed, or from ſome precipitation of part of the air, or be a compound reſulting from the union of ſome part of the inflammable body with the air or any of its component parts, has not yet been aſcertained.* When this Gas has been abſorbed by water or by lime-water, the remaining part of the air is alſo noxious and unfit for maintaining flame.

Air diminiſhed by burning ſubſtances is no longer capable of maintaining fire. Dr. *Deſaguliers* obſerves that Air which had paſſed through burning coals into an exhauſted receiver immediately extinguiſhed flame.

Air is not capable of ſuffering more than a limited diminution by burning ſuſtances. The diminution of the bulk of a quantity of air included in a receiver in which a candle was allowed to burn as long as it could, was found by Dr. *Hales* to be equal to $\frac{1}{28}$th part of the whole quantity of included air, and by Dr. *Mayow* to be $\frac{1}{30}$th, and by Dr. *Prieſtly* to be $\frac{1}{15}$th or $\frac{1}{18}$th. This

* This Gas cannot be produced from an inflammable body merely by heat without combuſtion; for when the focus of a burning glaſs was thrown on a bit of charcoal ſuſpended in a receiver filled with any other Gas than common air and inverted into a veſſel containing lime-water, no precipitation of the lime-water was occaſioned. *Prieſtly*. I. 136.

This diminution is obſerved to vary in different circumſtances. Dr. *Hales* obſerved that air ſuffered a greater diminution in equal receivers by large, than by ſmall candles; and alſo with equal candles, in ſmall, than in large receivers. Probably the candles extinguiſh as ſoon as all the air in contact with, or near their flame, has ſuffered its alteration; for by other modes of combuſtion, the air has been made to ſuffer a much greater diminution. Thus Mr. *Cavendiſh* found that air was diminiſhed $\frac{1}{10}$th by paſſing through an iron tube filled with red hot powder of charcoal. (*Prieſtly*, I. 129.)

And Dr. *Prieſtly* has diminiſhed the air much more by throwing the focus of a lens or of a concave mirror, upon a bit of charcoal ſuſpended in a receiver, I. p. 47.

I have produced a diminution equal to $\frac{1}{6}$th part of the included air by making the candle while it burns move quickly through the different parts of the inverted receiver, and thereby bringing the flame into contact with more of the air, than when the candle remains in one ſituation till it extinguiſhes.

13. *Air promotes the calcination of Metals*; and it is alſo diminiſhed by this operation, which is conſidered by Chemiſts as a ſpecies of combuſtion or ſlow inflammation.

This diminution, like that effected by burning ſubſtances, *cannot be carried beyond a certain proportion to the whole quantity of air employed.* Accordingly, Father *Beccaria* found by expoſing filings of lead and tin to heat in veſſels hermetically ſealed, that only a part of theſe metals could be calcined, and that this part was proportionable to the capacity of the veſſels employed. [*Mem. de l'Acad. de Turin* 11.]

After

After the air has suffered its utmost diminution by calcining metals, it is no longer capable of promoting any further calcination.

The *diminution of Air by the calcination of metals* has been found by Dr. *Priestly* to be equalto $\frac{3}{4}$ths of the whole quantity of Air. Vol. I. p. 134 †. But M. *Lavoisier* estimates this diminution only at $\frac{1}{15}$th or $\frac{1}{16}$th.

Air diminished by calcination differs from the air diminished by burning substances in this respect, that it *does not occasion a precipitation in lime-water*, the reason of which difference is assigned by Dr. *Priestly* to be that the calx seizes the part of the air, which is precipitated, in preference to the lime. Vol. I. p. 136.

The water however over which metals have been calcined acquires a yellowish tinge and an exceedingly pungent smell and taste. *Id.* 135.

14. *Metals acquire weight by calcination*, and the air which has assisted in this process, is thereby diminished. These facts seem to shew that something is absorbed during calcination by metals from the air (‡).

This absorption of air, or of some part of air, is further rendered probable from the elastic fluid that has

† This very great diminution of air was effected by throwing the focus of a burning mirror, orlens upon bits of lead and tin suspended in a glass receiver.

‡ The first person who ascribed the acquisition of weight by calcining metals to the absorption of air was *Jean Rey*, who has written expressly on this subject, in a book entitled, *Essais de Jean Rey, Docteur en Medicine, sur la recherche de la cause pour laquelle l'Etain et le plomb augmente de poids, quand on les calcine*. A Bazas 1630. This author attributes the encrease of weight to the adhesion of the denser part of the air to the calxes, while the more subtle part of this fluid, which prevents the adhesion of the air to other substances is separated during the calcination.

has been obſerved to eſcape during the reduction or revival of metallic calxes, and from the loſs of weight ſuſtained by them during that operation.

A very pure air may be expelled from *Minium* and from *Mercurius Calcinatus*, by application of heat, as Dr. *Prieſtly* has happily diſcovered. But it is doubtful whether this acceſſion of very pure air to minium and calcined Mercury be eſſential to theſe ſubſtances as calxes; for no ſuch air has been obtained from any other metallic calx merely by means of heat.

Boyle, *Lemery*, and other Philoſophers, have attributed this encreaſe of weight to the *particles* of *fire* or *flame*, which they ſuppoſed to be abſorbed by metallic calxes. *Charas*, a Chemiſt cotemporary with *Lemery*, aſcribes this effect to the *acid* of the *wood*, or of the *coal*, employed in the calcination.

M. *Venel* and M. *Morveau* maintain that this encreaſe of weight is not occaſioned by the addition of any ſubſtance to the metallic matter, but by *depriving* this matter of its *phlogiſton*. For, theſe philoſophers pretend that phlogiſton is endowed with a power contrary to that of gravitation, namely, of receding from the center of the earth, and thereby of rendering bodies, of which it makes a part, lighter than they otherwiſe would be. It is evident that a doctrine attributing to this phlogiſton, (a ſubſtance which is not the object of any of our ſenſes) a property directly contrary to *gravitation*, which is an undoubted property of all thoſe ſubſtances that are objects of our ſenſes) requires to be ſupported by very deciſive experiments and unequivocal arguments.

15. *Air is diminiſhed by exhalations of liver of ſulphur*, and of various *inflammable ſubſtances*.

Mr.

Mr. *Boyle* relates that a quantity of *air was totally absorbed by oil of turpentine* and *spirit of wine* mixed together. [*Boyle's works, vol. V. p.* 113.] Dr. *Hales* found that air was absorbed by the *pyrophorus of Homberg*; and Dr. *Priestly* observed that diminutions of air were occasioned by *liver of sulphur*; by a cement composed of *turpentine and bees-wax*; by *white paint*; and by *red-lead and oil.* Vol. II. p. 182.

Dr. *Hales* found that a mixture of *sulphur and filings of iron* formed into a paste with water diminished air; and the diminution has been estimated by Dr. *Priestly* to be equal to $\frac{1}{4}$th or $\frac{1}{5}$th of the air employed. [*Priestly vol. I. p.* 105.] This diminution was equal whether the experiment was made over mercury or over water. The diminished air was found to be lighter than common air; and it did not precipitate lime-water; the cause of which has been attributed to the acid of the sulphur dissolving the lime, and thereby preventing its precipitation. [*Priestly, vol. I. p.* 105.]

16. *Air is diminished by exposure to putrefying substances.* At first an elastic fluid is frequently generated, by which the bulk of the air is encreased, but in eight or ten days, the air is reduced to about $\frac{4}{5}$ths or $\frac{5}{6}$ths of its original dimensions. [*Priestly, vol. I. p.* 78.

17. *Air is diminished by respiration of animals*, as Mr. *Boyle* first observed. Vol. IV. p. 122. The diminution was found by Dr. *Hales* to be about $\frac{1}{13}$th of the whole air employed.

Air diminished by respiration *precipitates lime-water*, as Dr. *Macbride* observed.

18. Various other substances and mixtures have been observed to diminish air, among which are the following.

a. Lime mixed with *water. Hales.*

b. Lime mixed with *Sal Ammoniac. Hales.*

c. Lime

c. Lime mixed with *Acids*. *Hales*.

d. Marine acid extricated by pouring vitriolic acid on Sea-salt, or on sal ammoniac. At first some fluid was generated, probably what has been lately called *Marine air*. *See Chap.* 11. *on Marine acid Gas*. *Hales*.

e. Volatile alkali mixed with *iron*. *Hales*.

f. Volatile alkali mixed with *copper*. *Hales*.

g. Iron-filings mixed with *water*. *Hales*. M. *Lavoisier* found that the diminution of air by iron-filings and water amounted to $\frac{1}{4}$th part of the air in the space of two months; and Dr. *Priestly* observed that the air thus diminished could not be further diminished by nitrous Gas. *Priestly II. p.* 182.

h. Dr. *Hales* observed that air was diminished in the *distillation of aqua-fortis*, and by the mixture of *aqua-fortis* with *copper ore*, or with *pyrites*, or with *coal*. But Dr. *Priestly* says that the pure nitrous acid vapour does not alter air. Vol. II. 171.

i. Volatile sal ammoniac during its sublimation. *Hales*.

k. Sulphur subliming. *Hales*.

l. Vinous Gas. *Boyle III*. 144. *See Chap.* 3*d*.

m. Nitrous Gas. *Hales*. *See Chap.* 10.

n. Electric sparks. The electric spark being made to pass through a quantity of air included in a glass tube, in which also was contained some water tinged blue with turnsole, diminished the air $\frac{1}{5}$th, and changed the blue colour of the liquid to a red. *Priestly I*. 184. When the electric spark was taken in air over lime-water, the lime was precipitated. *Id.* 186.

o. Concentrated Vinegar. *Priestly II*. 27.

p. Nitre which has been melted and is cooling was observed by Dr. *Priestly* to injure common air. II. 167.

q. Vitriolic acid Gas was observed by Dr. *Priestly* to injure common air. II. 209. See ch. 9.

Air

Air which has been once diminiſhed to its utmoſt by any one of theſe proceſſes cannot be further diminiſhed by a repetition of that proceſs, or by any of the other diminiſhing proceſſes. *Prieſtly* I. 132.

19. *Air is neceſſary to animal life*, as is well known from the fatal effects of encloſing animals in exhauſted receivers, or in receivers filled with any other Gas or vapour. Some inſects however are ſaid to live well in vacuo. *Muſchenb. Introd. ad Phil. Nat* § 2167.

The air that has once ſerved for the reſpiration of animals is unfit to be again reſpired, and is *fatal to life*. The *quantity* of air employed for reſpiration by a man is computed by Dr. *Hales* to be a *gallon* in every *minute*.

From the noxious quality of reſpired air, we may be induced to give credit to travellers who relate that animals are killed by the breath of whales, and eſpecially by the breath of an immenſe ſerpent that inhabits the banks of the river Amazon ;† the air reſpired by theſe very large creatures being ſufficient totally to invelope ſmaller animals, and to exclude the air during a ſmall portion of time, which, however is ſufficient for this noxious air to produce its fatal effect.

The more denſe the air is, the longer it is capable of ſuſtaining the life of animals, as appears from the experiments of Mr. *Boyle.* Nevertheleſs, a *rarefied air*, provided it be frequently renewed, ſuſtains life very well. *Condamine* lived ſeveral weeks upon the Peruvian mountains, where the air was ſo rare that the mercury of the barometer was no higher than fifteen inches and nine lines.‡ An *Air* alſo *exceedingly denſe* may

† See *Don Ulloa's Voyage.*

‡ See *Bouger's Voyage to Peru.*

may be with ſafety reſpired. Divers ſometimes breathe under bells an air nine times denſer than the air of the atmoſphere.

20. Not only the air diminiſhed by reſpiration is *noxious* to animals, but alſo the *air in which inflammable ſubſtances have burnt*; the air in which *hepar of ſulphur*, and other *fumes of inflammable ſubſtances* have exhaled; the air in which ſubſtances have undergone the *putrefactive fermentation*, and perhaps moſt, if not all other kinds of *diminiſhed air*, are *noxious* to animal life, and alſo *extinguiſh flame*. *

21. Almoſt all exhalations, vapours, and fumes, when in conſiderable quantity make the air unfit for reſpiration. The vapour of pure water threw a bird into great anxiety; the vapour of vinegar had the ſame effect; vapour of ſpirit of wine killed a bird; and the

*Nevertheleſs Mr. *Boyle* obſerved that animals lived *nearly* as long in air in which candles had burnt, as in the ſame quantity of common air; and Dr. *Prieſtly* confirms the obſervation by his own experiments. But we may remark that this obſervation does not ſhew that air is not vitiated by burning ſubſtances, but only that animals can bear a greater degree of depravity of air than is occaſioned by the burning of candles. For, we find that the diminution of air by a burning candle is computed by Dr. *Hales* to be only $\frac{1}{28}$th part of the whole quantity, and by Dr. *Prieſtly* to be $\frac{1}{18}$th; whereas the diminution produced by the reſpiration of animals is no leſs than $\frac{1}{5}$th part of the whole quantity of air reſpired; and therefore an animal continues to breathe long after the air is incapable of promoting the inflammation of a candle. But although flame be generally extinguiſhed when the air has ſuffered an inconſiderable diminution, yet by throwing the focus of ſolar rays on a bit of charcoal, the air may, by means of combuſtion thus promoted, be diminiſhed as much as it can by any other method, that is, $\frac{1}{5}$th of the whole quantity. ——No experiment has ever been adduced to ſhew that air thus diminiſhed as much as it can be by burning ſubſtances, is not noxious and fatal to animal life. See § 12.

the vapours of oil of turpentine, oil of olives, and of ſpirit of ſal ammoniac were alſo found to be fatal to life. *Muſchenb. Introd. ad Philo. Nat.* § 2049. The vapour of newly plaſtered walls and of granaries are known to be noxious. *Laghius* found that the ſmell of camphor and of muſk was fatal to animals. *Comm. Bonon, tom.* 3. We ſhall hereafter ſee that every ſpecies of Gas, common air excepted, is noxious; and, they have been all obſerved to be more ſuddenly fatal than a vacuum is: hence, it is evident, that their noxious quality does not depend merely on their preventing the acceſs of air, or from their want of any principle, which may be ſuppoſed to render air neceſſary to life, but from ſome inſtant and immediate effect on the organs of ſenſation. Animals may be rendered leſs ſenſible of the diſagreeable impreſſion and leſs liable to be injured, by being gradually habituated to it, as Dr. *Prieſtly* has obſerved. I. 72.

22. Some attempts have been made to reſtore vitiated air, and render it again fit for reſpiration. Dr. *Hales* ſays that he cleanſed air, which had been reſpired, by making it paſs through flannel imbibed with ſalt of tartar; and that he prolonged the combuſtion of a candle in a given quantity of air by the ſame operation. The flannel employed gained weight. Theſe experiments, and alſo the precipitation of lime-water by means of air diminiſhed by burning ſubſtances or by reſpiration, ſeem to ſhew that in the air thus diminiſhed, there is ſome elaſtic fluid, ſimilar to that which commonly combines with alkaline ſalt and calcareous earths, and which has been generally diſtinguiſhed by the name of *fixed air*. See chap. 6. But as in air vitiated by reſpiration or by burning ſubſtances, not only this fixable part is noxious, but alſo the reſiduum after the fixable part has been ſeparated

by being absorbed in water, is found to extinguish flame and to be incapable of sustaining life, the above method of Dr. *Hales* cannot be very effectual. Dr. *Priestly* says that by long-continued agitation in water, he has restored all vitiated airs, whether by respiration, putrefaction, combustion, calcination of metals, a mixture of filings of iron with sulphur, or by white paint. Was this melioration of airs produced by the water absorbing the vitiated part, or by the agitation effecting a kind of circulation between the common external air and the vitiated air included in the jars, by which means much of the former pure air might be received into the vessels, while the vitiated part might be absorbed by the water and thrown out into the open air?

The *Count de Saluces* pretends that air injured by combustion could be meliorated by *cold* and by *compression*. But Dr. *Priestly*, from experiments purposely made, has refuted that pretension. I. 48.

23. *Air is necessary to vegetation* or the *life of plants*. In vacuo, plants do not grow, and seeds buried too deep under ground do not vegetate. A renewal of air is also necessary to the health of plants; for in confined air, they are generally weak and sickly.

M. *Cygna* affirms that plants included in a given quantity of air diminish this air, and soon languish and die; and that if other plants be afterwards introduced into the same receiver, they presently die without occasioning a further diminution of the air. Nevertheless, it would appear from Dr. *Priestly*'s experiments that plants can live long in confined air without sensibly diminishing or rendering the air unfit for maintaining flame or animal life. A sprig of mint having been put into a glass jar inverted into a vessel of water, during

ing ſome months, the air was found not to be vitiated. *Prieſtly.* I. 5.

Dr. *Prieſtly* found that plants grew not only in confined air, but alſo in air vitiated by the flame of a candle, or by reſpiration: and even that the vitiated air was frequently reſtored or at leaſt meliorated by the vegetation of the included plants. He put ſprigs of mint growing in water into different veſſels filled with air, in ſome of which candles had burnt till they ſpontaneouſly extinguiſhed, and in others the contained air had been reſpired, and he found that after the plants had been growing a few days, the contained air was ſo much meliorated that candles burnt in it, and animals could reſpire it. (*Vol.* I. *p.* 51.) From theſe experiments he infers, that *vegetation is one of the means employed by nature to purify air tainted with reſpiration, putrefaction, or combuſtion.*

But plants can tolerate only a certain degree of injury to the air in which they are placed; for Dr. *Prieſtly* relates that when growing ſprigs of mint were put into air ſtrongly and recently tainted with putrefaction, they *preſently died.* I. 86.

It is not however improbable that plants are capable of reſiſting a certain and even a conſiderable degree of putrid air; for ſeveral kinds of plants and alſo animals are known to inhabit thoſe places chiefly where a putrid effluvium prevails, which they ſuſtain without injury, and even perhaps with advantage to their peculiar conſtitutions. Further, animals and vegetables, while living, ſeem to poſſeſs ſome peculiar property of reſiſting putrefaction. For animals are known to live many days without food, and without any appearance of putrefaction, which however begins to take place a few hours after death. Alſo, vegetables are endowed

with a fimilar power; for the water in which plants grow, though it contain much vegetable putrefcent matter, does never putrify, while the plants live and are in health, but no fooner is the life or the health of the plant deftroyed, than the putrefaction begins. This fact is popularly known to perfons who keep fprigs of mint, hyacinths or other flowers, growing in glafs veffels filled with water.

Hence the plants which grow in ftagnant waters probably retard the corruption of thefe waters. *See Prieftly.* II. 185.

Perhaps this important fact in animal and vegetable economy may be explained, by faying, that *fermenting* fubftances do generally affimilate to their own nature, in a certain degree, many other fubftances, with which they happen to be mixed; and that the fermentations which are continually proceeding in the fluids of living animals and vegetables, overcome the putrid or other noxious ferments, if thefe be not too ftrong, in the fame manner as the vinous fermentation refifts putrefaction, according to the experiments of *Sir John Pringle* and Dr. *Macbride*. Hence the more ftrongly thefe natural fermentations proceed, that is, the more powerful is the *vis vitæ* of animals and plants, the more eafily are noxious ferments overcome, and infections refifted.

The purification or melioration of the tainted air included in receivers in which growing plants were placed, may be attributed not only to the abforption of the noxious vapour by the plants themfelves, but in fome meafure alfo, to the abforption of this effluvium by the water in which the receiver was inverted, and more confiderably by the watery vapours or perfpiration exhaled from the plant itfelf, which are known

to

to be very great relatively to the ſmall ſpace within the receiver. Theſe vapours may be conſidered as water with an exceedingly enlarged ſurface, and therefore capable of producing its utmoſt effect by abſorption of the diffuſed noxious ſubſtance. The vitiated particles being thus abſorbed by the watery vapours floating in the receiver might have been precipitated when the vapours were condenſed by the evening colds; and by the conſtant ſucceſſion of evaporation and condenſation, which muſt have taken place in the receiver, the whole quanity of ſuch particles may have been abſorbed and precipitated, and the remaining air thereby purified.

While therefore we accede to the inference drawn by Dr. *Prieſtly* from his very curious experiments, that "VEGETATION is one of the means employed by nature to purify air tainted by reſpiration, putrefaction, or by combuſtion;" may we not aſcribe a conſiderable ſhare of this grand and important effect to EVAPORATION, whoſe operation is more extenſive, penetrates to greater heights, prevails on the middle of the ocean and in frozen regions where few vegetables appear; and may not plants be alſo conducive to this effect in a great meaſure by exhaling vapours abundantly, and be in this reſpect, conſidered as inſtruments of evaporation.

The vitiated particles in the air thus abſorbed by the copious vapours which exhale from the ſurface of the earth and of the ocean, are raiſed along with theſe into the higher regions of the atmoſphere, and thence again fall along with the condenſed vapours or rain upon the earth. Thus diffuſed and united with water, perhaps reſolved into their component parts, they are not hurtful to animals and vegetables, but enter pro-

 bably

bably along with the water into their veſſels, combine with their fluids, and conſtitute part of their ſubſtance. From the animal and vegetable matters, theſe particles may be again expelled by various fermentations, putrefaction, and combuſtion; and thus, like moſt other kinds of matter, may undergo a perpetual circulation.

24. Philoſophers have formed various opinions concerning the nature of the air; ſome conſidering it as a peculiar element, others as a ſubſtance formed of water, and others as a compound body conſiſting of various elaſtic fluids, in which many heterogeneous bodies occaſionally float.† Some experiments lead to a belief of its being compounded. *S'Graveſande* ſays that a much greater portion of a bubble of air can be abſorbed by water on the firſt, than on any ſucceeding day, and thence infers that ſome parts are more diſpoſed to unite with water than others, and that the waters which are expoſed to the open air are chiefly impregnated with the former kind of aerial particles, which are accordingly obſerved, when expelled from the water and collected, to be different from the maſs of common air. *Inſtit.* § 654. And Dr. *Prieſtly* obſerved that when $\frac{4}{5}$ths of a quantity of air had been abſorbed by boiled water, the remainder was ſo different from the common maſs of air, that it extinguiſhed flame. I. 158.

Some philoſophers conſidering the action of air in maintaining the inflammation of combuſtible ſubſtances, have ſuggeſted that in this operation, the air and the inflammable matter mutually decompoſe each other, and

† Boyle on the hidden qualities of the air. S'Graveſande, Inſtit. Phil. Nat. § 646.

and that their parts form new combinations; consequently that the air is a compound body. *See the Dictionary of Chemistry, article* Air.

25. That an *Acid exists in Air* has been maintained by many chemists, some thinking that it is the vitriolic, others that it is the nitrous, and lastly others that it is the marine. But although all these acids are occasionally carried up with other vapours into the atmosphere, yet that an acid is a principle or component part of the air has not been ascertained from any decisive experiments made by these chemists. Dr. *Priestly* has however published lately an account of some experiments which seem to shew not only the existence of an acid as a principal component part of the air, but also that this acid is the *nitrous*. At least, he produced by means of heat from the nitrous acid mixed with various earthy substances a permanently elastic fluid or Gas, which possessed all the distinguishing properties of air. He found that this factitious air maintained the flame of combustible substances, and the respiration of animals; that it diminished *nitrous Gas*; and exploded with *inflammable Gas*; both which effects are properties of common air, as we shall afterwards shew.‡ And these properties were possessed by this fluid in a greater degree than by the air itself. For the flame was much brighter, the respiration much longer continued, the diminution of nitrous Gas much greater, and the explosion with inflammable Gas was much louder, by means of this factitious air, than when an equal quantity of atmospherical air was employed; and the difference between them is so great, that he computes the factitious air to be capable of producing

‡ See the chapters on *Nitrous Gas*, and on *Inflammable Gas*.

producing five, or six times the effect as common air, in all these instances. He therefore considers this factitious Fluid as a true and pure air, and thinks that the purity of the atmospherical air has been injured by the vapours with which it is always more or less mixed. He chiefly attributes the contamination of atmospherical air to the phlogiston contained in the vapours mixed with the air, and the greater purity of his factitious fluid to its not being mixed with phlogistic vapours; and he therefore distinguishes it by the name of *dephlogisticated Air*.‡

26. As the production of this Factitious Air is one of the most important discoveries that have been made concerning the constitution of the atmosphere, it will not be improper to mention more particularly the various means by which it has been obtained by Dr. *Priestly*, to whose successful labours the philosophical world is much indebted for the extension of its knowledge on this and all the other subjects of this Treatise. —He moistened with spirit of nitre various kinds of earthy

‡ That the burning of inflammable substances renders the air in contact with them unfit for respiration, or for maintaining flame, is well known. But that this change is induced by the air combining with the phlogiston, or principle, on which the inflammability of bodies is supposed to depend, has never been proved by experiments. However plausible this theory may be, it is not so well established, that any newly discovered substance should receive its name from thence. It would be less exceptionable to distinguish it by a name derived from the nitrous acid, from which it is made, if the term *nitrous Air* had not been already applied to denominate a peculiar kind of Gas obtained also from nitrous acid, but which is very different in all its peculiar properties; or from some sensible quality of this fluid, as *deflagrating Air*, from the singular and vivid deflagration which it occasions in any burning substance, and which is much more striking and remarkable than the inflammation usually produced by common Air.

earthy ſtubſtances, as *minium*, *flowers of zinc*, *chalk*, *clay*, *gypſum*, *magneſia*, *wood aſhes*, *flints*, and *Muſcovy-talk*, and put the earthy ſubſtance thus moiſtened into a gun-barrel, or into a glaſs phial, into the neck of which was ground a bent glaſs tube. He immerſed the noſe of the gun barrel, or of the glaſs tube into water, and placed over it an inverted jar filled with water. Upon applying heat to the part of the gun-barrel which contained the mixture, or to the bottom of the phial, a Gas, or elaſtic fluid was expelled from the mixture, and paſſed into the inverted jar. By changing the jar frequently, he was able to examine the Gas obtained at different periods of the operation. Thus he obtained from each of the above-mentioned earthy or metallic ſubſtances, moiſtened with the acid of nitre, conſiderable quantities of air, ſome part of which he found to be very pure, and other parts to be mixed with a Gas which extinguiſhed flame and precipitated lime-water, and with the nitrous Gas.

The *quantity* of air obtained from an ounce meaſure of flowers of zinc moiſtened with ſpirit of nitre was nearly three pints.

From theſe experiments Dr. *Prieſtly* is induced to infer, that the *nitrous acid is thus converted into pure air*; that it is always *one of the conſtituent parts of atmoſpherical air*; and that the other conſtituent parts of this fluid, are *earth* and as much *phlogiſton* as is neceſſary not only to its elaſticity, but alſo to reduce the purity of the air to the ſtandard at which it is commonly found.

The opinion that an acid is contained in air is further rendered probable by the change of colour induced on the tincture of turnſole by the electric ſpark paſſing through air in contact with that liquor. (See §. 18. n.) This experiment ſeems to ſhew that the electric ſpark decompoſes the air and diſengages its acid.

27. Some

27. Some other methods have been discovered by which a pure air may be obtained without the aid of the nitrous acid.

Dr. *Priestly* found that after he had absorbed by long continued agitation in water as much as he could of the several kinds of Gas, such as the inflammable Gas, and that obtained by mixture of calcareous or alkaline substances with acids, (called by him and other Authors *fixed Air)* that the residuums had the properties of common air, and he thence infers that *common air is thus generated.* I. 40. 68. †

28. Dr. *Priestly* says that he extracted pure Air by applying heat to *sedative salt*, to *Roman vitriol*, and to *salt-*

† This inference seemed to me to be liable to two objections. 1. In the apparatus described for procuring these Gases, there must always have been some small portion of common air mixed with the Gas. 2. By a long continued agitation of the Gas in water exposed to the atmosphere, there would probably be some particles of common air continually absorbed by the water, and afterwards separated from the water into the vessel containing the Gas. In order to obviate these objections, I procured some Gas from chalk and oil of vitriol, by means of an apparatus previously filled with boiled water, so that no common air could be mixed with the Gas obtained; and I let the Gas remain exposed to a considerable surface of clean boiled water till $\frac{5}{10}$ths were absorbed by the water, without agitation. I passed this residuum four times through lime-water, till it occasioned no more precipitation of the lime, by which operation, it was further reduced to a 3d, that is, to a 30th of its original quantity. This last residuum I found so pure air that a candle burned in it, and it diminished as much nitrous Gas as common air does. This production of common air from calcareous and alkaline substances, is a very remarkable phenomenon, and deserves further investigation. I found that the residuum of Gas obtained from potash, and treated in the same manner as I had done that from chalk, had the same properties. The residuum of a Gas obtained by distilling cream of tartar was chiefly inflammable, but seemed

falt-petre. The quantity thus obtained was very fmall, not exceeding the bulk of the materials. II. 86.

29. By expofing *red lead*, or *calcined mercury* to the focus of the burning glafs, Dr. *Prieftly* expelled from thefe fubftances air which feemed in its deflagrating and other properties to refemble the air obtained by means of nitrous acid. § 26.

The quantity however of air thus obtained merely by heat from thefe fubftances was very fmall. *Pr. II.* 37.

30. By applying *vitriolic acid* to *red lead*, I have obtained a large quantity of air, which feems to poffefs all the properties of the pure factitious air produced by means of nitrous acid ; § 26.

EXPERIMENT.

Forty-eight pennyweight of red lead were put into a long necked retort, the contents of which were ten cubic inches; and upon this red lead twenty-four pennyweight of oil of vitriol were poured. The nofe of the retort was then immerfed under water, and over it an inverted jar filled with water was placed. The mixture of red lead and oil of vitriol became very hot, and ten cubic inches of air were foon thrown into the jar, without the application of external heat. Upon applying the flame of a lamp to the bottom of the retort

feemed to contain fome portion alfo of common air, for a fmall diminution was obferved upon mixing it with nitrous Gas.

But Air cannot be thus produced from every one of thofe Gafes, which from the property they poffefs of precipitating lime-water, have been confidered as of the fame kind with the Gas obtained from calcareous and alkaline fubftances, and have been comprehended under the general name of *fixed Air*. At leaft, I found that a Gas obtained by diftilling green vitriol, which extinguifhed flame, and precipitated lime-water, having been expofed to boiled water and to lime-water, till it could no longer occafion any precipitation in lime-water, left a refiduum which extinguifhed flame, and did not in any degree diminifh nitrous Gas.

tort, bubbles of air paſſed copiouſly into the jars, which were ſucceſſively changed, that the air received at different times of the operation might be examined. The quantity of air which had been expelled from the above mixture of red lead and vitriolic acid, was found to be 36 cubic inches, after the proper allowances for the air contained in the retort had been made.

A candle burnt very well in the air of the firſt jar, moſt of which was common air that had been expelled by the heat and vapours of the mixture.

A lighted candle being put into ſome of the air of the ſecond and ſucceeding jars, burnt with a very vivid white flame, and deflagrated in the ſame manner as in the air produced from nitrous acid.

One meaſure of this air being mixt with three ſucceſſive meaſures of nitrous gas, became very red, and the mixture was diminiſhed every time; ſo that very little more than one meaſure remained. According to this trial, this air is capable of diminiſhing about five times as much nitrous Gas as common air is.

The air being mixed with *inflammable Gas, produced a much louder exploſion* than common air does. (See chap. 12, on Inflammable Gas.)

A mouſe being put into a jar containing a quantity of this air, equal in bulk to eight ounces of water, lived in it one hour and a half, and then died. The air in which the mouſe had died, not only admitted a candle to burn in it, but even made the flame brighter than common air does; which ſeems to ſhew that the whole of the air had not been tainted with the reſpiration of the mouſe, but only the lower part of it, which had been in contact or level with the animal; and that probably, if the air had been made to circulate in the veſſel, the mouſe would have lived much longer.

It

It appears therefore that the air thus obtained from red lead by means of vitriolic acid, has the ſame properties and in the ſame degree as the air obtained by means of the nitrous acid. It has even one advantage over the latter air, that it is not liable as this nitrous air is, to be rendered impure and even noxious by the mixture of nitrous Gas. Its purity is therefore more certainly to be depended on; the materials of which it conſiſts are cheaper; and it accordingly ſeems preferable for any medicinal or economical purpoſes to which a pure deflagrating air ſhould be hereafter applied.

In order however to obtain this air in its greateſt purity, care ought to be taken that the oil of vitriol be pure, clear, and colourleſs, and that the red-lead be clean and well calcined, which may be known from brightneſs and intenſity of its red colour.

The quantity of air produced from 48 pennyweights of red-lead is above ſaid to be 36 cubic inches. If we ſuppoſe this air to be of the ſame denſity as common air, we ſhall find that the weight of the air obtained is about $\frac{1}{100}$th part of the weight of the red lead.§

§ I thought it the more neceſſary to be particular in the deſcription of this experiment and its effects, as Dr. Prieſtly has informed us that he had endeavoured to procure air from red-lead and vitriolic acid, but without any ſucceſs. Vol. II. p. 52. There cannot be any doubt that his experiment ſucceeded as he relates; and the difference of his reſult and mine muſt therefore depend on the difference of our methods of trial. It appears that he moiſtened the red lead with the vitriolic acid, and endeavoured afterwards to dry it, before he attempted to obtain any air from it; by which method I apprehend the greateſt part of the contained air was expelled, before the mixture was put into the apparatus for the extraction of air. For much leſs heat is neceſſary to produce air from red lead and vitriolic acid than from the nitrous acid and earthy ſubſtances. Dr. Prieſtly obſerves that no Air could be obtained from *red lead* and *marine acid. ibid.* And this obſervation agrees with the trials which I have made.

CHAP.

CHAP. III.

On Vinous Gas.

31. ALL *fruits*, *grains*, and other *vegetable* substances, while they undergo the vinous fermentation, emit a permanently elastic fluid, called by ancient chemists, *Spiritus Sylvestris*, which name was changed into *Gas Sylvestre* by *Van Helmont*, who observed its production and its properties, and distinguished it better from the common air than any of his predecessors. *Boyle* also has made various experiments shewing that an elastic fluid is extricated from fermenting substances, and that this fluid is different from common air.

32. The *quantity* of Gas expelled from fermenting substances was first attempted to be ascertained by Dr. *Hales*. From 42 cubic inches of beer, 639 inches of Gas escaped in seven days: and from 26 cubic inches of bruised apples 968 cubic inches of Gas were produced in 13 days. *Hales Analysis*. Mr. *Cavendish* found that $\frac{57}{100}$ parts of dry sugar were converted into Gas by the vinous fermentation; and that the quantity produced from the fermenting juice of apples was equal to $\frac{381}{1000}$ parts of the dried juice.

Dr. *Priestly* tried how much Gas could be extracted from different kinds of wines. From $1\frac{1}{2}$ oz. measure of each of the undermentioned wines he obtained the following quantity of Gas: Madeira

Madeira $\frac{1}{100}$ of an oz. meaſure.
Port, 6 years old, $\frac{1}{78}$ ditto.
Hock, 5 years old, $\frac{1}{27}$ do.
Barrelied Claret $\frac{1}{12}$ do.
Tokay, 16 years old $\frac{1}{20}$ do.
Champagne, 2 years old, 2 do.
Bottled cyder, 12 years old, $3\frac{1}{4}$ do.

Prieſtly, II. 227.

33. Vinous Gas is poſſeſſed of the following *properties:*

a. It *extinguiſhes flame*, as *Boyle* has obſerved in the Gas of fermenting paſte. IV. 125.

b. It is *noxious to animals* when reſpired, as *Boyle* has remarked. IV. 125. Accordingly numberleſs inſtances occur of the fatal effects of perſons inſpiring the air of cellars filled with fermenting liquors.

c. It is alſo *fatal to vegetable life*. Dr. *Prieſtly* obſerves that ſprigs of mint growing in water were frequently killed in a day or leſs by being placed over a fermenting liquor. Vol. I. p. 36.

d. It has been obſerved by Mr. *Boyle* to *diminiſh common air*. IV. 144.

e. It is *antiſeptic*; that is, it reſiſts putrefaction. *Boyle* obſerved that fruit was preſerved in this Gas better than in common air. IV. 144.

f. It is capable of being *abſorbed by water*, to which it communicates an acidulous taſte, like that of *pyrmont* and other mineral waters. Dr. *Hales* obſerved that the Gas obtained by adding vinegar to oyſter-ſhells was abſorbed by warm water. Mr. *Cavendiſh* diſcovered that ſome parts of this Gas were more eaſily abſorbed by water than others.

g. It *precipitates lime water*, *renders cauſtic alkalis mild*, and produces all the known effects of the Gas obtained

obtained from effervefcing mixtures of acids and alkalis. See therefore the properties of that Gas in the fixth chapter; all which properties are alfo applicable to vinous Gas.

34. Much elaftic fluid efcapes from liquors undergoing the *acetous fermentation*; but its properties have not been examined, nor can we certainly fay whether it be the fame as vinous Gas. Dr. *Prieftly* obferved that it diminifhed common air $\frac{1}{9}$th part; and that air thus diminifhed extinguifhed flame. I. 154.

CHAP. IV.

On the Gas extricated from putrefying fubftances.

35. A Permanently elaftic Fluid or Gas efcapes from animal and vegetable fubftances undergoing the putrefactive fermentation.

This Gas confifts of two different kinds mixed together. One of thefe renders cauftic alkalis mild, and precipitates lime water, as Dr. *Macbride* has fhewn. The other kind of Gas was obferved by Mr. *Cavendifh* to be *inflammable*. *See chap.* 12, *on inflammable Gafes.*

The quantity of thefe two kinds of Gas, which was obtained from four penny-weight and fix grains of mutton, during the putrefactive procefs, was found to be, in bulk, equal to $2\frac{1}{14}$ oz. of water, of which quantity $2\frac{15}{200}$ oz. meafures were of the former kind of Gas, and the remainder was inflammable. It is obfervable, that all the inflammable Gas was extricated in the beginning of the procefs. *Prieftley* III. 344.

From 7640 grains of putrefying broth, (which contained about 163 grains of folid matter) one grain of inflammable Gas was procured by Mr. *Cavendifh*. *Phil. Tranf.* 1766.

CHAP.

CHAP. V.

Of the Gas obtained by fire from Animal and Vegetable substances.

36. MUCH elastic fluid is produced in the distillation of animal and vegetable substances. Dr. *Hales* has ascertained the quantity of Gas which he procured from many of these substances. From his *Analysis of Air*, the following summary of the results of his experiments is collected.

1 cubic inch of *hog's blood* yielded	33 cubic inches of gas.	
½ cubic inch of *deer's horn*, —	117	equal to $\frac{1}{7}$th of its wt.
½ cubic inch of *oak* —	108 —	$\frac{1}{3}$ —
388 grains of *Indian wheat* —	270 —	$\frac{1}{4}$ —
1 cubic inch of *pease* —	396 —	$\frac{1}{3}$ ---
437 grains of *mustard seed*	270 —	$\frac{1}{6}$ —
142 grains of dry *tobacco* —	153 ----	$\frac{1}{3}$ ——
1 cubic inch of *oil of anniseed*	22	——
1 cubic inch of *oil of cloves* -	88	—
1 cubic inch of *honey* mixed with *calcined bones*	144 —	$\frac{1}{9}$ —
1 cubic inch of *bees wax* ----	54 ----	$\frac{1}{18}$
1 cubic inch of *coarse sugar*	126	$\frac{1}{16}$
1 cubic inch of *tartar* ----	504	$\frac{1}{3}$
½ cubic inch of *salt of tartar*	112	$\frac{1}{9}$
¾ cubic inch of *human calculus*	516	
⅙ cubic inch of *stones* taken from a human gall bladder	108	

Van Helmont computes that of 62 pounds of *charcoal*, 61 pounds may be reduced into gas by burning. *Complex. atq. mistion. elem. figm.* 13.

37. Mr. *Cavendish* observed that the gas produced by burning charcoal precipitated the lime of lime-water; and in general, we may remark, that the gases produced by analysing vegetable or animal substances render lime-water turbid, extinguish flame, and are noxious to animals, and also to vegetables, as Dr. *Hales* observed. [*Veg. Stat. ch.* 7.]

In these properties, they resemble the vinous gas, and the gases obtained from effervescing mixtures. Sometimes however, especially when the heat is strong or suddenly applied, an *inflammable gas* is produced by distilling animal or vegetable matters. Thus Dr. *Hales* observed that the Gas obtained in the analysis of *Pease* was inflammable. And it may be remarked generally that the elastic fluid produced by fire from animal and vegetable matters is chiefly a mixture of gas which occasions a precipitation in lime-water and extinguishes flame, and of another gas which is inflammable and which may be separated from the former gas by exposure to water; by which means the inflammable gas will be left alone, the other being almost totally absorbed by the water. The inflammable gas thus obtained separate from the other is not quite pure; for I found that a gas obtained by distilling tartar, which did not shew any marks of its containing common air when mixed with nitrous gas, being exposed to water and lime-water, till no more could be absorbed, left a residuum which was inflammable, and which on being mixed with nitrous gas, became turbid, and was a little diminished; which shews that the residuum contained a small portion of common air.

CHAP.

CHAP. VI.

Of calcareous Gas; or the Gas expelled from calcareous and alkaline ſubſtances by fire or by acids. †

38. A Permanently elaſtic fluid is extricated by heat, or by acids, from *fixed* and *volatile alkalis*, from *magneſia*, *chalk*, *marble*, *lime-ſtone*, *marine ſhells*, and all thoſe ſubſtances called *calcareous*, or which, by calcination are convertible into quicklime.

39. The *quantity* of gas obtained from the above ſubſtances was found to be as follows.

108 grains of *crab's eyes* diſſolved in 1½ oz. of diſtilled vinegar produced in vacuo 81 cubic inches of Gas. *Boerhaave.*

1 dram of *chalk* diſſolved in two ounces of diſtilled vinegar produced 151 inches of gas in vacuo. *Boerhaave.*

Two drams of *crab's eyes* with 1 oz. of vinegar produced 12 cubic inches of Gas. *Eller. Berlin Mem.*

† This Gas and alſo the vinous Gas, and indeed all others which have been found to occaſion a precipitation in lime-water have been comprehended under one name, *Fixed Air*. But although they agree in that property and a few others, their origin is ſo various, that they can ſcarcely be conſidered as one ſubſtance, till they have been further examined. I have therefore treated of them ſeparately.

Two drams of *crab's eyes* with 1 oz. of ſpirit of ſalt produced 75 cubic inches of gas. *Eller.*

Two drams of *red coral* with 1 oz. of ſpirit of ſalt produced 52 cubic inches of gas. *Eller.*

Magneſia contains half its weight of Gas. *Black. Edinburgh Eſſays.*

Marble contains $\frac{407}{1000}$ parts of its weight of gas. *Cavendiſh. Phil. Tranſ.* 1766.

Lime-ſtone contains $\frac{1}{3\frac{3}{4}}$ of its weight of gas, and $\frac{2}{32}$ of water. *Jacquin, Examen Doctrinæ Meyerianæ.*

Cremor calcis contains $\frac{1}{3\frac{3}{2}}$ of its weight of gas. *Jacquin.*

Chalk dried with the heat of boiling mercury contains $\frac{448}{1407}$ of its weight of gas. *Lavoiſier. opuſc. Phys.* 1.

One dram of *ſalt of tartar* with $\frac{1}{2}$ an oz. of ſpirit of nitre yielded 48 cubic inches of gas. *Eller.*

Cryſtals of ſalt of tartar yielded $\frac{423}{1000}$ of their weight of gas. *Cavendiſh.*

Cryſtals of ſoda yielded $\frac{576}{3715}$ of their weight of gas. *Lavoiſier.*

Volatile ſal ammoniac yielded $\frac{528}{1000}$ of its weight of gas. *Cavendiſh.*

Volatile ſal ammoniac yielded $\frac{768}{1620}$ of its weight of gas. *Lavoiſier.*

40. The *ſpecific gravity* of this gas was found by the Hon. Mr. *Cavendiſh,* to be to that of water as 1 to 511; or to that of air, when this is 800 times lighter than water, as 157 to 100. According to Mr. *Lavoiſier* the ſpecific gravity of this gas is to that of air as 561 to 455.

41. The *properties* of *calcareous earths* and of *alkalis are very much altered* by combination with this gas. For, when *limeſtone* or other calcareous earth are, by calcination or otherwiſe, deprived of the gas uſually combined

bined with them in their natural ſtate, they are thereby converted into *quicklime*. Alſo when *alkalis fixed* or *volatile* are deprived of their gas, by any means, they are thereby rendered more cauſtic, incapable of effervefcing with acids and of cryſtallization, and more powerfully ſolvent, as Dr. *Black* has proved by accurate and adequate experiments. *Edinburgh Eſſays*.

The ſame excellent Chemiſt has alſo ſhewn that by recombining this gas with quicklime, magneſia, or alkalis, which had been previouſly deprived of it, their former weight and properties might be reſtored. From the greater acrimony communicated to quicklime and to alkalis by depriving them of their contained gas, he has diſtinguiſhed them when thus deprived, or uncombined with gas, by the epithet *cauſtic*, as *cauſtic calcareous earth*, or *cauſtic fixed alkali*, or *cauſtic volatile alkali*; and when theſe earths or alkalis are combined with gas, he calls them *mild*.

Dr. *Black* contrived an apparatus by which the gas extricated from an effervefcing mixture could be conveyed into a cauſtic alkaline liquor, and ſhewed that by this method, the cauſtic alkali could be rendered mild, and could recover its effervefcing and cryſtallizing properties. His apparatus conſiſted of two phials communicating by means of a bent tube, one end of which is inſerted into the mouth of one phial, and the other end into the mouth of the other phial. In one of the phials he put ſome cauſtic ſpirit of ſal ammoniac, and into the other phial he put ſome mild alkali or mild calcareous earth. Upon this mild alkali or earth he poured through a hole purpoſely made in the ſide of the phial, ſome acid liquor, which immediately produced an effervefcence as uſual, that is, it extricated from the alkali or earth their contained gas.

 The

The gas being thus disengaged passed through the bent tube into the phial containing the spirit of sal ammoniac, with which it combined, and which it changed from a caustic to a mild state. For the spirit is by this process rendered capable of effervescing with acids, and if it be much concentrated, it will be seen to crystallize during its impregnation with gas.

Dr. *Macbride* employed a similar apparatus to impregnate lime-water with gas, by which means he changed the caustic earth or quicklime which was dissolved in the water to a mild calcareous earth, which not being soluble in water as quicklime is, was therefore precipitated. *See Macbride on the dissolvent power of Quicklime.*

42. Dr. *Black* has further determined by experiments the relative powers of the several alkaline substances to unite with this elastic fluid, or the *affinities* of this fluid towards these substances. He found that this gas was more disposed to unite with *caustic calcareous earth* or *quicklime* than with any other substance; next with *fixed alkali*; then with *magnesia*, and lastly with *volatile alkali*.

Consequently mild volatile alkali may be deprived of its gas or rendered caustic by applying to it magnesia previously deprived of its gas, or caustic fixed alkali, or quicklime; and at the same time the magnesia, fixed alkali, or quicklime are thereby rendered mild. Magnesia also may be deprived of its gas by means of caustic fixed alkali, or of quicklime; and lastly, mild fixed alkali may be rendered caustic by means of quicklime which is at the same time rendered mild. Hence soap-boilers in order to increase the activity or dissolving power of their alkali, boil it in water with quicklime.

According

According then to this doctrine, the *causticity* and other *peculiar properties* of *quicklime* and caustic *alkalis*, are the *original properties* of these substances, while they are *pure* and *uncombined*; and are not communicated to them by any supposed absorption of matter from the fire in calcination, as *Meyer* and other Chemists maintain. †

43. This gas is capable of adhering to, or combining with, *metallic precipitates*. Thus when a mild alkali or calcareous earth is added to a solution of a metal in an acid, the alkali or earth unites with the acid, the metal is precipitated, and the gas of the alkali or earth, which would have occasioned an effervescence if the acid had not been united with a metal, does not in this case produce any effervescence, but unites with and increases the weight of the metallic precipitate. Dr. *Black*, who

 first

† This Theory, which has been ably investigated, has thrown much light on many chemical phenomena. But although it is well supported by the decisive experiments related by Dr. *Black*, (*Edinburgh Essays*,) it has nevertheless met with much opposition from some German and French chemists who adopt the theory of M. *Meyer*, concerning the principle which he called *Acidum pingue*, of which an account is given in the Dictionary of Chemistry. *See* ACIDUM PINGUE. On the other side, Dr. *Black*'s doctrine has been ably supported and confirmed by M. *Jacquin* in a treatise called *Examen chemicum Doctrinæ Meyerianæ de Acido pingui et Blackianæ de acre fixo*. And this treatise has been attacked by M. *Crantz* in his *Rectificatio Examinis chemici Doctrinæ Meyerianæ*, &c. As not only the reasonings but also the facts related by these authors were contradictory, M. *Lavoisier*, of the academy of Sciences at Paris, undertook a series of Experiments with a view of ascertaining the several questions in dispute; an account of which he has published under the title of *Opuscules physiques & chymiques. Vol.* 1. These experiments which seem to have been made with accuracy and ability, can leave no doubt of the validity of Dr. *Black*'s experiments and deductions.

first observed the union of this fluid to metallic precipitates, attributes the fulminating property of *aurum fulminans* to the gas which adheres to the gold precipitated by a mild alkali The adhesion of gas to metallic precipitates is confirmed by M. *Lavoisier*.

The precipitation of some metallic solutions seems therefore to be effected by what Chemists call a double affinity; that is, the gas of the alkali unites with the precipitated metal, while the acid unites with the alkali. Accordingly the precipitation of some of these metals requires that the precipitating alkali be mild, that is united with gas. Thus, silver dissolved in nitrous acid cannot be precipitated by a caustic volatile alkali, altho' it may very perfectly by a mild volatile alkali.

This gas not only assists the precipitation of metals from their acid menstruums, when it is combined with alkalis, but even sometimes effects this precipitation, without the aid of an alkali. At least, there is one instance of such precipitation, when this gas is added to a solution of sugar of lead, as Mr. *Hey* of *Leeds* has observed. *See Appen. to Priestly's* 1st. *vol. of Obs. & Exper.*

44. This Gas is capable of being *absorbed by water*, and the water thus impregnated precipitates the lime from lime-water, as Dr. *Macbride* has shewn.

The quantity of gas which water at the temperature of 55° of Fahrenheit's scale can absorb, was found by Mr. *Cavendish* to be more than equal to the bulk of the liquid, and to be greatest when the water was cold, and compressed by an heavy atmosphere.

The water thus impregnated acquires a *subacid taste*, like that of the mineral waters called *acidulous*, and it also acquires a *greater density*; the specific gravity of distilled water impregnated with gas being to that of distilled

tilled water not impregnated, as 1000322 to 1000000, according to an experiment made by *M. Lavoiſier. opuſc. phys. & chym. Tom. I. p.* 210.

45. Gas abſorbed by water may be thence expelled by removing the preſſure of the atmoſphere from its ſurface by means of an air-pump; or by boiling the water, or by freezing the water. The greateſt part of the gas eſcapes merely by expoſure to the open air, eſpecially in warm weather.

46. This gas is alſo capable of being abſorbed by other liquors, as by *expreſſed oils* and by *ſpirit of wine*, which laſt liquor is found to be capable of abſorbing 2 $\frac{1}{4}$ times its bulk of gas. *Cavendiſh.*

47. This gas *extinguiſhes flame*: and even a mixture of nine parts of common air with one part of this gas does not admit a candle to burn, as Mr. *Cavendiſh* has obſerved. *Phil. Tranſ.* 1766.

48. This gas when reſpired is *fatal to breathing animals*. Dr. *Prieſtly*, however, remarks that inſects and animals which breathe very little are ſtifled in this fluid, but are not ſoon killed; that Butterflies and other flies generally become torpid and ſeemingly dead after being held a few minutes over a fermenting liquor; but revive on being brought into freſh air. *I. p.* 36.

49. This gas *reſiſts putrefaction*, as Dr. *Macbride* has proved, from experiments. He ſhews that by applying this gas to putrefying ſubſtances, their putrefaction is impeded; and he even pretends that they are hereby reſtored from a putreſcent to a ſound ſtate. He ſupports the opinion of Dr. *Hales* that Gas is the cementing principle of the particles of the ſolids and fluids in which it is contained, and that therefore when this is expelled, by fermentation, putrefaction, or otherwiſe, the coheſion of theſe particles muſt be diſſolved;

diſſolved; and when it is reſtored, they may thereby recover their original conſtitution. But why is this gas conſidered as the cement or connective inſtrument more than any of the other principles which enter into the compoſition of theſe bodies? For by depriving a body of any of its conſtituent parts, the coheſion of the whole muſt be diſſolved, whether the principle thus taken away be gas, or earth, or acid, or alkali?

From many experiments Dr. *Prieſtly* is led to think that this Gas is capable of correcting the noxious quality of air tainted with putrefaction. I. 99. 101.

50. This gas when united with water is capable of *acting upon and diſſolving calcareous earth, magneſia, iron,* and perhaps ſome other metals. Mr. *Cavendiſh* firſt obſerved its property of diſſolving calcareous earths, and that although it at firſt precipitates the earth from lime-water, yet it afterwards re-diſſolves this earth. He has alſo ſhewn that the calcareous earth contained in *Rathbone-place* waters is kept diſſolved by no other menſtruum than this gas. † The ſame fluid is probably the ſolvent of the calcareous earth contained in all thoſe waters which depoſite their earthy ſediment upon expoſure to air.

Mr. *Lane* diſcovered that diſtilled water impregnated with the gas of fermenting or effervеſcing ſubſtances was capable of diſſolving iron, and that the water thus impregnated with the gas and iron had a vinous ſmell and taſte, like thoſe of ſome chalybeate waters, in many of which he thinks the iron is diſſolved merely by means of gas. Hence a mild and pleaſant chalybeate water may be made by putting filings of iron in water impregnated with the gas obtained from

† Phil. Tranſ. 1766, 1767.

from fermenting and effervescing substances. Not only iron in its metallic state, but also some of the *calciform ores of iron* may be dissolved in water impregnated with gas, as Mr. *Rouelle* found by experiment. (*Lavoisier. Opuscules I. p.* 156.

This Gas occasions a *precipitation* in a solution of *Sugar of lead*, as Mr. *Hey* of *Leeds* observes. (*Appendix to Dr. Priestly*'s 1st. Vol.) And this precipitation I have found takes place whether the Gas employed has been obtained from calcareous and alkaline substances, by vitriolic acid or by nitrous acid. This precipitate may be redissolved by adding nitrous acid.

51. The Gas obtained from calcareous and alkaline substances does not seem to be one homogeneous fluid, but rather a compound or mixture consisting of different kinds of Gas: For, Mr. *Cavendish* observed that some parts of it were much more easily absorbed than the rest; and that about $\frac{1}{50}$th or $\frac{1}{30}$th part of it could not be more readily absorbed by water than common air can. Dr. *Priestly* found that the residuum which could not be absorbed by water had some of the properties of common air, namely, that it effervesced with nitrous gas, (which is a test of common air, as shall be hereafter shewn) and that it was not noxious to a mouse, although it was not so pure that a candle could burn in it.

52. Several circumstances concerning this Gas lead to an opinion that it is of an *acid nature*, or that an acid enters into and predominates in its composition. *See* § 133 *of this Treatise.*

CHAP.

C H A P. VII.

Of the Gases in Mines and other subterranean places.

53. A Noxious gas is found in many caverns, as in the famous *Grotta del cane*, in mines, wells, and other deep pits. This Gas, which by English miners is called *Choke-damp*, is heavier than common air, and therefore lies chiefly at the bottom of pits; extinguishes flame; precipitates the lime of lime-water; and is noxious to animals: From these properties which it possesses in common with the gas obtained from calcareous and alkaline substances, it has been reckoned to be of the same kind, and described under the name *Fixed Air*. *See a note* † *chap* 6. ‡

54. Another kind of gas found in mines and other deep pits, is called *Fire-damp*, from its inflammability. It is lighter than air, floats near the roofs of mines, and is apt to catch fire and explode. This is one of the Gases of which we shall treat under the name of *Inflammable Gas*. *See chap.* 12.

CHAP.

‡ Miners who work in mines that are subject to this damp, generally carry down with them into their pits a lighted candle to try the salubrity of the air. They can however remain with safety several hours in pits where a candle cannot burn. I have seen them working in the shaft of a coal-pit several yards below the part of the shaft where a candle was extinguished. For, as has been already observed in treating of the gas of effervescing substances, a smaller quantity of noxious gas being mixed with air is sufficient to extinguish flame than to prevent respiration. But where the damp is so strong, that not only the flame of the candle, but also the redness of the burning wick is extinguished, they never venture to remain a minute, knowing that degree of damp to be quickly fatal to animal life.

CHAP. VIII.

Of the Gas of Waters.

55. AN elaſtic fluid may be expelled from *common water* by *removing the preſſure of the atmoſphere*, by *boiling*, or by *freezing*. But although the greater part of the air or gas may be expelled by theſe means from water, yet Mr. *De Luc* ſhews from many laborious experiments that water obſtinately retains a certain quantity of air or gas, which cannot be extricated by boiling, by the air-pump, or by any other known means, than by a long continued agitation in vacuo; and he further ſhews, that when water is thus deprived of all the air that can be ſeparated from it, it then becomes capable of ſuſtaining, without boiling, a much greater heat than can be given to it in its common ſtate, even to 240° of Fahrenheit's ſcale, or more.

56. From 54 cubic inches of well-water, Dr. *Hales* obtained one cubic inch of elaſtic fluid; and from a pint of pump-water Dr. *Prieſtly* procured $\frac{1}{4}$ of an ounce meaſure of a gas, in which a candle could not burn, but a mouſe lived. I. 160. The water of another pump yielded $\frac{1}{4}$ of its bulk of gas. I. 160. II. 225.

57. A much larger quantity of gas is contained in many *mineral waters*. Thus from 54 cubic inches of *Pyrmont* Water, Dr. *Hales* procured two cubic inches of

of gas, which he seems to have erroneously considered as common air: And from 411 ounces of the water of *Rath-bone-place*, Mr. *Cavendish* obtained above 75 ounce measures of gas, of which quantity he observes, not above twenty measures were extricated before the water boiled. *Philos. Trans. vol.* 57.

Some Authors talk of a much larger quantity of gas being contained in some water. Thus *Mariotte* affirms that a bubble of elastic fluid expelled by heat from water, did occupy, when reduced to the temperature of the atmosphere, a space, ten times greater than the space occupied by the water which had contained it.

But Dr. *Hales* suspects that part of this gas produced in *Mariotte's* experiment, (which was made by applying heat to a drop of water included in a glass thimble filled with oil and inverted in oil) proceeded from the *oil*: For oil also contains a considerable quantity of gas, according to Dr. *Hales's* experiments. (*Hales Appendix.*)

Other mineral waters yield a very small quantity of gas by being heated. *Bath-water* yields only $\frac{1}{30}$th of its bulk of Gas according to an experiment of Dr. *Priestly*; and of this quantity, one half had the properties of the Calcareous Gas, and the other half of Air in which a candle had burnt out. II. 223. Dr. *Hales* procured no more gas from two quarts of Bath-water than was equal in bulk to half a pea. *Appendix*.

58. Dr. *Hales* justly attributed the peculiar briskness and sparkling quality of Pyrmont and other mineral waters to the gas which he found was contained copiously in them. *Hoffman* also observed that some mineral waters in Germany, contained nothing saline but that they abounded in a volatile principle, to which

which he gives the name of *Sulphureous aereo-ethereo-elastic spirit.* And Mr. *Venel* shewed in 1750 that the waters of *Seltz* were neither acid nor alkaline, but contained $\frac{1}{5}$th of their bulk of an elastic fluid to which they owed their peculiar properties: And he endeavoured to imitate this mineral water, by adding to a French Pint of water two gros of mineral alkali, and a sufficient quantity of marine acid, to saturate the alkali. This mixture being made in a strait-necked close vessel, the gas which was expelled from the alkali by means of the acid was not allowed to escape; but it impregnated the water, so strongly, that this water was found to contain twice as much gas as the native mineral water.

Mr. *Venel* does not however distinguish the gas contained in mineral waters from common air.

Dr. *Seyp* of Pyrmont in the year 1736 considered this fluid to be the same as that which is found in the Grotta del Cane and other subterranean places: And Dr. *Brownrigg* sent to the Royal Society a paper in which the gas of Pyrmont and Spa-waters are said to be analogous to the choke-damp or permanently elastic gas of mines. *Phil. Trans. vol.* 55.

Mr. *Cavendish* observed that the gas obtained from the waters of *Rath-bone-place* occasioned a precipitation in lime water, and he is induced to believe that the greatest part of it is of the same nature as the gas contained in calcareous earths. But he also found that $\frac{875}{7500}$ of the gas contained in this water were common air.

59. Mr. *Cavendish* discovered that calcareous earth is suspended and dissolved in the waters of many Springs, by means of their contained Gas.—By an accurate

curate analysis of the waters of *Rathbone-place*, he obtained, from 494 ounces of these waters, 271 grains of earth, which, excepting a few grains of magnesia, was of the calcareous kind. He further shews, as has been already remarked, that the gas obtained from calcareous or alkaline substances is capable of dissolving calcareous earth, that is, of making it soluble in water. It may seem extraordinary that this gas which is known to precipitate the lime from lime-water, should also render this earth soluble in water; but the fact is uncontravertible; for besides that this or some very similar gas is proved to be the medium by which the calcareous earth is kept suspended in *Rathbone-place* and other waters; it is shewn by Mr. *Cavendish*, that, if to lime-water which has been rendered turbid by means of gas, more gas be added, this water will by this addition be enabled to redissolve the precipitated lime, and will be again rendered pellucid. And indeed this phenomenon is analogous to other well known chemical facts. For many of the precipitates, formed by adding alkalis to the solutions of metals in acids, may be redissolved by a further addition of the alkaline precipitant.

60. Mr. *Lane* has shewn that the Gas of mineral waters is capable of *dissolving iron*; and that by means of this fluid, without any other menstruum, the iron is dissolved and suspended in many chalybeate waters. These chalybeate waters deposite their iron when exposed to air; for the gas, by means of which it is suspended, is volatile, and escapes upon exposure to air †. But Dr. *Brownrigg*,

† Dr. *Hales* had observed that when *mineral watres* had been deprived of their elastic fluid, they lost their power of tinging an infusion of galls. (*Appendix.*) And indeed *Van Helmont*, long before, knew that the escape of the spiritous gas, from these waters, by exposure to air, was accompanied with a loss of their acidulous quality, and a depositian of the ferruginous matter dissolved in them. *Paradoxum quartum.* § 2, 9, 10.

Brownrigg, has obſerved, that the gas does not eſcape from the water which it impregnates, unleſs the water be in contact with air; for when the *Pouhon* water was excluded from air, but at the ſame time liberty was given for its gas to riſe into an empty bladder, the gas did not ſeparate from the water by any ſpontaneous motion, but on the contrary, it remained united with the water, when expoſed to the greateſt heats of our climate. When the impregnated water is thus excluded from air, the gas will eſcape but ſlowly with any heat leſs that of 110° of Fahrenheit's thermometer, although ſuch heat be ſufficient for the diſtillation of water; neither can this gas be wholly expelled by a heat of 160° or 170° continued two hours. This adheſion ſhews that the gas exiſts in the mineral water with the other ingredients in a ſtate of ſolution, and in the ſame proportion in which the Gas is expelled, in the ſame alſo are the martial and earthy parts ſeparated. *See Dr. Brownrigg's paper on Pohoun waters. Phil. Trans. vol.* 64.

There is reaſon to believe that the Gas may be more intimately combined with the ingredients of ſome mineral waters than with thoſe of others, and cannot be ſo eaſily expelled. Dr. *James Keill* obſerved that a mineral water near Northampton loſt its ſpiritous quality by being long kept included in a Florence flaſk hermetically ſealed. The combination of the Gas with the water may have been rendered more perfect by time. Perhaps the reaſon why ſo little Gas can be extricated from Bath-water (See §. 55.) may be that it is more intimately combined with that water, or united with other ingredients which retain and fix it more than in the waters of Pyrmont, and others which ſparkle much.

61. Gas may be *separated from water* not only by the means mentioned in § 55, but also by addition of an acid, which occasions an effervescence and consequently an escape of the gas. Hence the acidulous waters are made to sparkle by adding juice of lemons, or Rhenish wine.

62. The discovery of Gas being the principle to which the briskness and peculiar properties of the mineral waters called acidulous are principally owing having been ascertained; and Dr. *Hales* and Mr. *Cavendish* having shewn that the gas of calcareous substances was capable of being absorbed by water; (§ 33 and 34,) it occurred to Dr. *Priestly* that the artificial impregnation of water with gas might be applied to useful purposes, and that mineral waters might be thus imitated. It was observed that the water which had been distilled from sea-water, although free from any saline matter, was not so palatable or brisk as pump-water. This defect Dr. *Priestly* proposed to supply by impregnating the distilled water with the gas extricated from chalk by means of oil of vitriol. And he published an account of an easy method of effecting this impregnation. His method consisted in collecting a sufficient quantity of this gas in a bladder; and in forcing the Gas from the bladder through a bent tube into the water intended to be impregnated; which water was contained in a bottle inverted into a bason filled also with water. The Gas thus remaining in contact with the surface of the water within the inveced bottle, is gradually absorbed, and the absorption is hastened by agitating the apparatus. The water when impregnated acquires the taste of the acidulous mineral waters; and accordingly this artificial impregnation of water with Gas has been lately much practised,

practiſed, in order to imitate theſe mineral waters. Dr. *Percival* obſerved that the water thus impregnated acquires more of the ſparkling quality of Pyrmont water by being kept ſome time. (*Prieſtly*, I. 32.)

This impregnation of water with Gas is much facilitated by Dr. *Nooth*'s invention of an elegant and well-contrived apparatus of glaſs veſſels for this purpoſe, an account of which is publiſhed in the *Phil. Tranſ. vol.* 65.

63. The Gas contained in water is ſaid by ſome authors to be *more expanſive* than common air is; that is, that by an equal diminution of preſſure upon theſe two elaſtic fluids, the bulk of the former is much more enlarged than the bulk of the latter. *S'Graveſande* obſerved that a bubble of the Gas in water expanded ſo as to occupy a ſpace 15000 times greater; when the common air ſuffered an expanſion of only 300 times. And *Muſchenbroek* affirms that he has ſeen a particle of this Gas expand itſelf to a ſize 46656000000 times greater. But (he adds) ſuch particles are not always to be obſerved in water, and he conjectures that this Gas, as well as air, conſiſts of particles of different denſities and elaſticities. *Introd. ad Philoſ. Nat.* § 2051. 2063.

That theſe ſingular expanſions of bubbles of Gas in water appeared as is repreſented cannot be doubted when we conſider the accuracy and ability of S'Graveſande and Muſchenbroek. But that the Gas of water poſſeſſes an elaſticity ſo much greater than common air is an inference not eaſily to be admitted. And may not this phenomenon be otherwiſe explained? Water and other liquids are known to retain ſo powerfully the air or other elaſtic fluids which happen to be united with them, that theſe elaſtic fluids cannot be *immedi-*

ately thence expelled, either by boiling or by removing the preſſure of the atmoſphere; but while the liquids remain freed from this preſſure, the air or other elaſtic fluid ſeparates from them very ſlowly and gradually, forming a bubble which becomes more and more large from the gradual acceſſion of exceedingly ſmall and almoſt inviſible particles of ſuch elaſtic fluid. This very ſlow ſeparation of air from liquors and the gradual formation of bubbles was particularly noticed by *M. de Luc* when he was making thermometers. It ſeems therefore probable that the enlargement of the bubbles obſerved by the Dutch Philoſophers did not proceed merely from an expanſion of a given quantity of air or other elaſtic fluid, but principally from the acceſſion of more particles of this fluid diſengaging themſelves from the water during the experiment, and uniting with the bubbles ready formed.

Muſchenbroek ſays alſo that by *doubling* the preſſure he reduced the elaſtic vapours of a fermenting paſte to a quarter of its former ſpace: And he thinks that moſt elaſtic fluids are not ſubject to the ſame law as air is, namely, that the ſpaces occupied by them are inverſely as the powers with which they are compreſſed. (*Introd. ad Phil. Nat.* § 2051.)

As Muſchenbroek does not relate the manner in which the above-mentioned experiment was made, we cannot ſay whether ſome error might not ariſe from condenſation of watery vapours or abſorption of Gas. A different reſult however was the conſequence of the following experiment.

I filled a bent tube open at one end only with ſome Gas obtained by adding vitriolic acid to chalk. By pouring mercury into the tube, a quantity of this Gas was included between the cloſe end of the tube and the

the ſurface of the mercury. I meaſured the ſpace occupied by the Gas thus expoſed to the compreſſion of the atmoſphere, and alſo of the column of mercury in the open leg of the bent tube above the ſurface of that fluid in its cloſed leg. I then varied the height of this column of mercury by pouring more of this fluid into the tube, and I obſerved the reſpective diminutions of ſpace which the gas ſuffered from the encreaſed compreſſions. By comparing the ſeveral obſervations which I had made, I found that the ſpaces occupied by the Gas under different preſſures were to each other inverſely as their reſpective compreſſing forces, and conſequently that this elaſtic fluid is ſubject to the ſame law in this reſpect, as common air is. †

† The bulk of every permanently elaſtic fluid is probably in the inverſe proportion to its preſſure, with the ſame *heat*. But as concrete bodies are ſubject to very different expanſions by equal degrees of heat, ſo alſo are gaſes. Dr. Prieſtly has made experiments to meaſure the expanſions of ſeveral of theſe fluids, while the mercury of Fahrenheit's thermometer was expanded 10 degrees. The proportions of theſe expanſions to each other are expreſſed in the following table.

Common Air	—	1. 32
Inflammable Gas	—	2. 05
Nitrous Gas	—	2. 02
Calcareous Gas	—	2. 20
Marine acid Gas	—	1. 33
Deflagrating Air	—	2. 21
Phlogiſticated Air	—	1. 65
Vitriolic acid Gas	—	2. 37
Alkaline Gas	—	4. 75

CHAP. IX.

On Vitriolic acid Gas.

64. THE *Vitriolic acid* is capable of being raised by means of heat, and of mixture with *oils* or other *inflammable substance*, into an elastic fluid, which is not condensable by cold, as Dr. *Priestly* has shewn. (II. p. 7.)

65. This Gas is very readily *absorbed by water*; when thus brought into the form of a liquid, it possesses all the properties of the vitriolic, or rather perhaps of the volatile vitriolic or sulphureous acid. As this Gas so readily unites with water, it therefore cannot be collected in vessels filled with this liquid, but with some fluid on which it has no action, as mercury.

66. The same kind of Gas may also be obtained by means of heat from concentrated vitriolic acid and several *metallic substances*, as copper, silver, lead, iron and zin. We shall afterwards see that a Gas of a different kind may be obtained from the same acid in a dilute state acting upon some of these metals. *See Chap.* 12 *on inflammable gas.*

67. The *properties* of this Gas as observed by Dr. *Priestly* are,

a. It was *heavier than common air.*

b. It *extinguished flame.*

c. It *dissolved ice* very fast.

d. It was *absorbed by charcoal*, to which it communicated a very pungent smell.

e. It *dissolved camphor* readily, and reduced it to a transparent liquor, from which, by addition of water, camphor was re-produced.

f. It did *not act* upon iron, nitre, common salt, or sal ammoniac.

g. It formed a *white cloud* upon being mixed with a vapour of *volatile alkali*.

h. It *injured common air*. II. 209.

i. When *electric sparks* were passed through this gas included by means of quicksilver, in a glass tube, the sides of the tube became tinged with a black stain. II. 209. †

† The same stain is produced when the electric spark, and more effectually when the electric shock is made to pass through common air confined by quicksilver. This black matter when heated appears to be pure quicksilver. Priestly, III Pref. p. 34.

CHAP. X.

On nitrous Gas, and on nitrous acid Gas.

68. VAN HELMONT observes that when nitrous acid is added to any metal soluble in that acid, a quantity of gas is produced sufficient to burst the strongest glass vessels, if vent be not given to it. And he carefully distinguishes this gas from the vapour of the acid, such as is raised in distillation, and is again condensed in the receiver. *De flatibus*, § 67.

Dr. *Hales* also obtained this Gas by distilling *nitrous acid* with a *martial pyrites*: and also by mixing that acid with *antimony*; or with *mercury*; or with filings of *steel*: (*Hales's Append.*)

This Gas may be distinguished by the name of *nitrous Gas*. †

Dr. *Priestly* procured the same Gas by dissolving in the nitrous acid any of the following metals, *iron*, *copper*, *tin*, *mercury*, *silver*, *bismuth*, or *nickel*, and also by dissolving *gold* or *regulus of antimony* in aqua regia. He obtained little or no Gas by dissolving *lead* in nitrous acid; and he found that the Gas produced by dissolving *zinc* in that acid had the properties of the nitrous Gas only in a small degree. (*Priestly, Vol. I. p.* 110 *and* 126.)

69. Nitrous Gas possesses the following *properties*.

a. Dr. *Hales* observed that when this Gas was mixed with common *air*, these two fluids *unite* together, and produce *heat* by their union; the mixture becomes *red*

† It is called by Dr. Priestly, *nitrous air*

red and *turbid*; and its quantity or *bulk* is found to be confiderably *lefs* than that of the two fluids employed.

Dr. *Prieftly* obferves that the diminution of a mixture of this Gas and of common air is not an equal diminution of both the kinds, but (fays he) "of about "one fifth of the common air and as much of the *ni*-"*trous air* as is neceffary to produce that effect; which, "as I have found by many trials, is about one third "as much as the original quantity of common air. "For if one meafure of nitrous air be put to two "meafures of common air, in a few minutes (by "which time the effervefcence will be over and the "mixture will have recovered its tranfparency) there "will want about $\frac{1}{9}$th of the original two meafures; "and if both the kinds of air be very pure, the di-"minution will go on very flowly, till in a day or "two, there will remain only one fifth lefs than the "original quantity of common air." *Vol. I. p.* 110.

When air is once faturated with the nitrous Gas, any further addition of Gas occafions an equal encreafe of the bulk of the mixture, and produces no heat or rednefs.

The nitrous Gas fuffers no diminution upon being mixed with any other kind of Gas than air, and confequently the diminution is greater when the air is purer, as Dr. *Prieftly* has obferved. And he has accordingly very happily applied this nitrous Gas, as a teft, to *diftinguifh* air from other kinds of Gas, and to *meafure its purity*.

b. This gas *extinguifhes flame*. *Hales App*.

c. It is *noxious to animals*. But frogs and fnails were obferved to live in it a confiderable time, although they died at laft in it. *Prieftly*, *I*. 119. 226.

d. Diftilled *water abforbs* about $\frac{1}{10}$ of its bulk of this gas; and the water thereby acquires an acid tafte, and

and becomes covered with a film. † Nitrous Gas was by long *agitation* in water rendered capable of being *diminished by fresh nitrous Gas*, as air is; and when by this agitation it was reduced to $\frac{1}{11}$th of its original bulk, a mouse could live in it. *Priestly*, *I.* 189. 120.

e. Nitrous Gas being exposed to a large surface of *iron* during two months, was rendered *capable of maintaining flame*, and even enlarging the flame, although it continued highly noxious. The same effects were produced by exposing nitrous Gas to *liver of sulphur*, during twenty four hours; (*Priestly*, *I.* 216. 217. *II.* 178,) and to a mixture of filings of iron and sulphur. (*Id. III.* 141.

A Gas, possessed of this inflammable property, may be procured by dissolving tin or zinc in nitrous acid. It may also be obtained by applying heat to a solution of iron in that acid, after the common nitrous Gas had escaped from it during the solution, without heat. Priestly, III. 133. &c.

f. Nitrous Gas was diminished, by exposure to *iron-filings and sulphur* made into a paste with water, to $\frac{1}{4}$th of its original dimensions. When it has been thus diminished by iron-filings and sulphur, the residuum cannot be diminished by common air, nor by agitation in water. *Priestly*, *I.* 223.

g. The *electric spark* taken in nitrous Gas diminished this Gas to about $\frac{1}{4}$th of its original quantity, and rendered it unfit for diminishing air. When this spark was taken while the Gas was in contact with a solution

† Mr. *Bewly* remarks that this Gas does not give to water a sensible acid impregnation, unless it comes into contact, or is mixed with a portion of air. *Priestly*. I. 318.

ſolution of archil in water, the colour of this ſolution was changed from blue to red, in a very great degree. (*Prieſtly*, *I.* 220. *II.* 238.)

h. Nitrous Gas was very ſuddenly and copiouſly *abſorbed* by *ſpirit of nitre*; the colour of which was thereby changed firſt to a deep-orange then to a green. The quantity of Gas abſorbed by a ſtrong ſpirit of nitre was in bulk 650 times greater than the quantity of ſpirit employed. Towards the end of the proceſs, the evaporation of the acid ſpirit was obſerved to be ſo very great, that, at laſt, only half the quantity of ſpirit remained, and this was further obſerved to be very weak. The abſorption of the Gas ſeems to have rendered the ſpirit very volatile. *Prieſtly*, *Obſ. and Exp. III.* 122. &c.

Oil of Vitriol was obſerved to abſorb about as much of this Gas as water does; and to be thereby rendered of a purple colour. *Id. III.* 129.

Spirit of Salt imbibed $\frac{1}{20}$th of its bulk of this Gas, and its colour was thereby changed from yellow to a ſky-blue. *Id. III.* 129.

This Gas was alſo abſorbed by concentrated *vegetable acids*. Id. III. 130.

i. Nitrous Gas has been obſerved by Dr. Prieſtly to be capable of *abſorption* by *oils*, *ether*, *ſpirit of wine* and by *cauſtic alkali*. The quantity abſorbed by oil of turpentine was conſiderable, being equal in bulk to eleven times the quantity of oil employed. The whole of a given quantity of Gas however could not be thus abſorbed; for a reſiduum, which extinguiſhed a candle and ſeemed to be like air which had been expoſed to burning ſubſtances, remained equal to $\frac{1}{4}$th of the quantity of Gas expoſed to the oil of turpentine. *Prieſtly*, *III.* 112. &c.

k. Nitrous

k. Nitrous Gas is presently decomposed by a solution of *green vitriol* in water; the colour of which is thereby rendered darker, but is restored to green, on exposing the solution to air. *Priestly, III. preface* 33.

70. Dr. *Priestly* thinks that this Gas consists of the vapour of the nitrous acid united with phlogiston, together perhaps with some small portion of metallic calx. I. 271.

And Mr. *Bewley* justly remarks, that this nitrous acid in form of a fluid, not condensable by cold, cannot be restored to a liquid state without the presence and admixture of air. (*Priestly Append. I.* 318.)

The red appearance therefore which takes place upon mixing nitrous Gas with air seems to proceed from the many small particles or minute drops of nitrous acid just reduced from an elastic state to that of a liquid; and these particles gradually subside, or are absorbed by the water, and disappear.

71. Not only the Gas above described may be obtained from the nitrous acid; but also the mere vapour of heated spirit of nitre was observed by Dr. *Priestly* to assume the form of Gas: at least, it remained uncondensed by the cold of the atmosphere to which it was exposed. II. 169.

The difficulty of finding a fluid capable of confining this vapour, and on which it has no action, prevented a complete investigation of it; for it was readily absorbed by water, and it dissolved quick-silver. Our knowledge of it is therefore very imperfect; but if it should be found upon further examination to be a permanent Gas, it may be denominated *Nitrous acid Gas*; while the Gas described in the preceding sections may retain the name of *Nitrous Gas*.

When

When this vapour was mixed with nitrous Gas, the mixture became red and turbid, the nitrous Gas was diminiſhed, and its power of diminiſhing air was leſſened. II. 170.

Dr. *Prieſtly*, to whom we are indebted for every thing we know concerning this Gas, not finding any liquor capable of containing it, threw this vapour, which he obtained from nitrous acid diſſolving metals, into phials containing air, by which means the phials, were filled with this vapour mixed with air. The vapour in theſe phials was obſerved to be red; and the intenſity of the red colour of this vapour, and alſo of the high-coloured ſpirit of nitre itſelf was encreaſed by heat. This phenomenon Dr. *Prieſtly* attributes to the action of heat on the phlogiſton contained in the vapour and acid.

This vapour being mixed with air, and afterwards ſeparated from the air by being abſorbed by water, was found to have ſo altered the air, that it was no longer capable of diminiſhing nitrous Gas. III. 192.

Water very readily abſorbs this vapour, and is thereby converted into a ſpirit of nitre, the colour of which varied according to the ſtrength of the impregnation, from blue to green and thence to a yellowiſh hue. III. 198.

During the beginning of the impregnation of the water with this nitrous acid vapour, the water was obſerved to ſparkle much; and the impregnated water gradually emitted ſo much elaſtic fluid during two or three days after the impregnation, that the veſſels, if cloſely ſtopt, were in danger of burſting. This elaſtic fluid was expelled more copiouſly by heat; and upon examination, was found to be *nitrous Gas*.

The

The quantity of this Gas which was expelled from impregnated water was in bulk ten times greater than the water employed. But it appears from Dr. Priestly's former experiments that water can absorb only $\frac{1}{10}$th of its bulk of nitrous Gas; therefore this large quantity of nitrous Gas does not enter as nitrous Gas mixed with the acid vapour into the water; but seems to be formed by the union of the vapour with the water.

This acid vapour united with expressed oils, rendered them of blue and yellow colours, and coagulated them. By combining with essential oils, it produced heat, effervescence, and once an explosion happened. III. 208. 210.

The Gas produced by the union of the vapour with oils was found to be similar in its properties to air which had been exposed to burning or phlogistic bodies. III. 211.

Oil of vitriol and spirit of salt imbibed this acid vapour. The spirit of salt thus impregnated became an aqua regia which readily dissolved gold; and when heated, it yielded a considerable quantity of nitrous Gas, in the same manner as the impregnated water was observed to do. But no gas could be expelled from the impregnated oil of vitriol. III. 222.

CHAP.

CHAP. XI.

On marine acid Gas.

72. CHEMISTS have remarked that a conſiderable quantity of elaſtic fluid is diſengaged during the diſtillation of ſpirit of ſalt by means of oil of vitriol. And *Van Helmont* obſerves that, upon adding nitrous acid to ſal ammoniac, ſo much *Gas* is produced, without application of heat, that the ſtrongeſt and largeſt veſſels will burſt, if vent be not given. *De flatibus*, §. 62.

Mr. *Cavendiſh* collected a quantity of this Gas, which aroſe from ſpirit of ſalt acting upon Copper. *Phil. Tranſ. vol.* 56. And Dr. *Prieſtly* has alſo procured it from the ſame ſpirit acting upon other metals, and even without addition of any metal or other ſubſtance, merely by application of heat to the marine acid. He conſiders therefore this Gas only as the marine acid reduced to an elaſtic ſtate, not condenſable, at leaſt by the common cold of the atmoſphere. Accordingly it had been obſerved that in the diſtillation of ſpirit of ſalt much of the ſtrongeſt vapour eſcapes uncondenſed; and Mr. *Woulfe*, in order to prevent this loſs, has invented an apparatus, by means of which the vapour is made to paſs repeatedly through water, and is thereby condenſed. (*Phil. Tranſ. vol.* 57.) For *water* very readily *abſorbs* this Gas; and thus a ſpirit of ſalt is compoſed; as

Dr. *Priestly* shews (*vol*. I. 148.) *Ice* is as quickly dissolved by this Gas, as it is by a hot fire. (Id. p. 240.)

73. This Gas *acts upon* many *metallic* and *inflammable substances*, and is thereby changed into an *inflammable Gas*, as is shewn in the following chapter. But the fumes of *liver of sulphur* did not render it inflammable: These fumes reduced its dimensions to one half. (*Priestly*, *I.* 235.)

Marine acid Gas was diminished by the *electric spark* passing through it. (*Priestly*, II. 239.)

74. This Gas *extinguishes flame*; and when mixed with air, it gives to flame a beautiful green or bluish colour. (*Priestly*, I. 147.)

CHAP. XII.

On inflammable Gases.

75. SOME Gases are found to be capable of being inflamed. These are procured from very different matters and by very different methods. Probably therefore *several kinds* of inflammable Gas may exist.

76. An inflammable Gas is frequently found in *mines*, especially *coal-mines*, which sometimes takes fire, and explodes with great danger to the miners.

77. Dr. *Hales* obtained an inflammable Gas by distilling *wax*, *pitch*, *oyster-shells*, *pease*, *amber*, and *coals*. Probably it might be obtained by applying heat suddenly to *any dry inflammable matter*, without excepting even the *inflammable* or *calcinable metals*. Dr. *Priestly* procured

procured inflammable Gases from clean filings of *iron*, *zinc*, *brass*, and *tin*, by exposing these separately to the focus of a burning lens, in vacuo; and likewise from *iron filings* and *chalk*. II. p. 107, &c. But he could not produce any inflammable Gas from *bismuth*, *regulus of antimony*, *nickel*, *lead*, or *copper*; nor from *metallic calxes*..

78. An inflammable gas may be produced by dissolving *iron*, *zinc* or *tin* in the *diluted vitriolic*, or *marine acids*.

According to experiments made by Mr. *Cavendish*, one ounce of zinc dissolving in either of the above acids produced a quantity of inflammable gas equal in bulk to 356 ounces of water; one ounce of iron dissolving in spirit of vitriol produced a quantity of gas equal in bulk to 412 ounces of water; and an ounce of tin produced as much gas as occupied the space of 202 ounces of water. Dr. *Priestly* has produced an inflammable gas by dissolving zinc and iron in radical vinegar; and by dissolving copper, lead, and regulus of antimony in spirit of salt. III. 255, 256. This water over which this gas is contained becomes covered with a thin film, which is red, like ochre, if the gas has been procured from iron, and is white if from zinc. Pr. I. 58.

79. *Marine acid gas*, or, the vapour of concentrated marine acid may be *changed into an inflammable gas* by acting upon inflammable substances, as *spirit of wine*, *oil of olives*, *oil of turpentine*, *charcoal*, *phosphorus*, *sulphur*; and also upon *dry cork*, *oak*, *ivory*, *beef*, and even *flint*. (*See Dr. Priestly*, *p. I.* 149 *and* 232.) This marine acid gas being exposed to *quicklime* till $\frac{1}{1}\frac{5}{7}$ were absorbed, the remainder was observed to be inflammable. (*Priestly*, *I. p.* 236.)

80. An inflammable Gas is expelled from *putrefying animal or vegetable matters*. The waters of some *rivers* into which much fermentable matter is washed, as of the *Thames* and the *Aluta*, after having been confined during a certain time in casks, emit an inflammable gas. Of the quantity of this gas which may be obtained from given quantities of putrefying matter. See chap. 4. § 35.

81. An inflammable gas exhales from *liver of sulphur*, upon adding an acid, as *Meyer* and *Rouelle* have observed. (*Lavoisier*, *I.* 161.)

82. *Cygna* observes that *air saturated with volatile alkali* is inflammable.

83. Dr. *Priestly* found that the *electric spark* taken in oil, ether, spirit of wine, or spirit of sal ammoniac, produced an inflammable gas. I. 242. 245.

84. The *quantity* of inflammable gas obtained was observed to be *greatest* when the *distillation* of inflammable matters was *hastily performed* and with a *heat suddenly raised*; or when the *solution of metals* in acids proceeded with the *greatest vehemence*, as when heat was applied, and acids of a proper strength were employed; and when the *putrefaction* of animal and vegetable matters was *hastily excited*. Priestly, I. 58.

85. The *specific gravity* of inflammable gas was found by Mr. *Cavendish* to be eleven times less than that of common air, when this is 800 times lighter than water.

86. Mr. *Cavendish* did *not* find that this gas was *absorbed by the water*, over the surface of which it stood: and it certainly may remain thus long without any considerable diminution. But Dr. *Priestly* says that by agitation in boiled water, no less than $\frac{3}{4}$ of

this

this gas may be absorbed and that the remainder was but weakly inflammable. I. p. 67.

87. Inflammable gas is *not diminished* by fumes of *liver of sulphur* or by the *electric spark.* Neither did the electric spark passing through this gas change the colour of a solution of archil in water. (*Priestly*, I. 247.) The effects of exposing this gas to *oil of turpentine* were remarkable. Its bulk was thereby considerably enlarged; it was rendered less inflammable; and it was made capable of diminishing nitrous gas nearly as much as air is. *Priestly, III.* 366.

88. The *contact of air* is necessary to the inflammation of this gas, as of other inflammable substances. Mr. *Cavendish* has made experiments to discover the effects of mixing different proportions of gas and air, previously to the inflammation; and he found the following results.

A mixture of nine parts of air with one part of inflammable gas, did not fire easily, and the inflammation was accompanied with little sound.

Two parts of inflammable gas and eight parts of common air, were easily fired, and the sound produced was moderately loud.

Three parts of inflammable gas and seven parts of air gave a very loud sound.

Four parts of inflammable gas and six parts of air gave a sound very little louder than the former mixture.

Equal parts of gas and air sounded like the last mixture.

In the first experiment, when nine parts of air were mixed with one part of gas, the flame spread gradually through the bottle containing the mixture. In the three next experiments, no light could be per-

ceived, perhaps becauſe the flame laſted too ſhort a time to make a ſufficient impreſſion on the eye. When equal parts of the two fluids were employed, a light was ſeen.

A mixture of ſix parts of inflammable gas and four parts of air produced a ſound which was not loud, and after the exploſion it continued to burn a ſhort time.

A mixture of ſeven parts of inflammable gas with three parts of air gave a gentle bounce and continued to burn ſome ſeconds.

A mixture of eight parts of inflammable gas with two parts of common air caught fire without noiſe and continued to burn only in the neck of the bottle.

From theſe experiments Mr. Cavendiſh infers, that unleſs the mixture contain more air than inflammable gas, the air is not ſufficient to conſume the whole of the gas, and that the remainder burns by means of air ruſhing into the bottle after the exploſion.

89. Inflammable gas is *noxious to animals*; but it does *not* ſeem to be *hurtful to vegetable life*; for Dr. Prieſtly found that plants grew pretty well ſeveral months in it, and that it ſtill continued inflammable. I. 61.

CHAP.

CHAP. XIII.

On Fulminating Gases.

90. SOME Gases are *so suddenly* extricated or formed from the substances containing them, by the heat applied, or by means of the action of the parts of these substances on each other, or by the concurrence of both these causes, that in the instant of their formation an *Explosion* or *Fulmination happens.*

91. A Gas of this kind is produced by the *deflagration of nitre* with inflammable substances. *Van Helmont. complex. &c. figment.* § 21. &c. Hence the explosion of *gun-powder*, and of the *fulminating powder* composed of nitre, salt of tartar, and flowers of sulphur.

The *quantity* of gas obtained from gun-powder was found by the experiments of Mr. *Robins* † to be equal in bulk to 244 times the bulk of the exploded gun-powder, when this gas is compressed by the atmosphere and reduced to the same heat: And as the expansion of the air appeared from his experiments to be increased four times by the heat of iron just beginning to be white, he infers that if the elastic fluid of gun-powder be equally affected by heat as air is, its

† Robins on Principles of Gunnery.

expanſive force in the inſtant of exploſion is nearly a thouſand times greater than the preſſure of the atmoſphere; a force ſufficient to produce the effects of gun-powder.

92. *Boyle* obſerved that the gas of gun-powder was *noxious* to animals. And Dr. *Prieſtly* found that the gas obtained by applying heat to a mixture of nitre and ſulphur was the *nitrous gas*. II. 90.

He ſuſpects however that when heat is ſuddenly applied, a kind of air may be obtained. For he found that in making the clyſſus of nitre with ſulphur, one twelfth part of the gas produced, precipitated lime from lime-water; and the remainder was ſimilar to air, which had been expoſed to burning ſubſtances. And when nitre was deflagrated with charcoal, one twentyeth part occaſioned a precipitation in lime water, and the remainder diminiſhed very conſiderably nitrous gas. III. 339.

93. Some *metallic precipitates* are capable of fulminating. The preparation called *fulminating gold* is well known. The gas produced during its exploſion has not been examined.

Mr. *Bayen* has diſcovered that various *mercurial precipitates* fulminate, when they are triturated with about $\frac{1}{6}$th part of flowers of ſulphur and afterwards heated. Of theſe precipitates the following are the principal.

a. Precipitates made by adding a *fixed alkali*, *mild* or *cauſtic*, or a *volatile mild alkali*, or *lime-water*, to a ſolution of *mercury* in *nitrous acid*.

b. Precipitates made by adding *fixed alkalis mild* or *cauſtic*, or *lime water*, to a ſolution of *corroſive ſublimate* in water.

c. A

c. A Precipitate or *mercurial calx* prepared by digesting, in a sand-bath, *Turbeth mineral*, with a solution of *fixed alkali* in water, till the precipitate became red.

Mr. *Bayen* remarks, that no detonation was produced by mixing these precipitates with powdered charcoal, and applying heat to the mixture, and also that the detonation was observed to be so much the stronger as the precipitates were more deprived of their acid. Thus the precipitate from the solution of mercury in nitrous acid by means of volatile alkali detonated very weakly, till it had been deprived of much of its adhering acid by calcination: And no detonation was produced by the precipitate which had been made by adding volatile alkali to a solution of corrosive sublimate in water; for it appeared upon exposing this precipitate to a subliming heat that the whole of it was in the state of sweet mercury, and that consequently much acid adhered to it.

94. The detonation of nitrous and other powders is an effect too striking not to have engaged the attention of philosophers. *Stahl* maintains that the water of the nitre is converted into air. M. *Macquer* very ingeniously conjectures that, in the operation, a *nitrous sulphur* is formed, which inflames at the instant of its formation. *(See the article "Detonation of nitre" of the Dictionary of Chemistry.)*

Dr. *Black* is of opinion that the fulminating gold derives its detonating property from some gas which adheres to it, and which it had received from the alkaline precipitant used in the operation. However this explanation may be applicable to the fulminating gold; it cannot be applied to explain the fulmination of the *mercurial precipitates* of Mr *Bayen*; for some of these were prepared by caustic alkalis and by quick-

 lime.

lime. Mr. *Bayen* thinks that the fulmination of these precipitates is the consequence of a commotion excited between the mercury and the sulphur at the instant of the combination taking place by which cinnabar is formed. And this opinion is confirmed by the heat and even spontaneous inflammation which happens when sulphur and crude mercury combine together.

Whatever be the cause which excites such commotions, the *detonation* itself consists in the sudden concussion which the air receives from the instantaneous production of an elastic fluid expanding itself with great violence. In the notes to the first English edition of the Dictionary of Chemistry I suggested, at the article *Fixable Air*, that the elastic fluid produced in the detonation of Nitre was formed from the *nitrous acid* probably combined with the *inflammable principle* and that these are *converted into the state of gas* by the violence of the action of this acid and of the inflammable matter on each other. This opinion of the *conversion of nitrous acid into gas* by the *detonation of nitre* has been since confirmed and established by late experiments, which shew first that the gas thereby produced is principally that which we have described under the name of *nitrous gas*, (§ 92.) and secondly, that this nitrous gas is the nitrous acid in the state of *gas*, probably combined with inflammable matter; and is again convertible into the liquid nitrous acid by being mixed with air. (§ 70.)

The detonation likewise of Mr. *Bayen*'s mercurial precipitates is occasioned by the production of an elastic fluid; and I think that this fluid also proceeds from the conversion of some adhering portion of the acid, in which the mercury had been dissolved, into the state

ſtate of gas, (together probably with ſome of the phlogiſton of the metal or ſulphur, by means of the violent heat and motion excited between the mercury and the ſulphur in the act of combination, while the mercury is forced from its union with the adhering acid. For, it appears both from Mr. *Bayen's* experiments, and from analogy of other precipitatations, that ſome acid always adheres to the precipitate; and probably alſo ſome of the alkaline or earthy precipitant. It is true indeed that when *much* acid adheres, the fulmination does not happen, as Mr. *Bayen* remarks. The reaſon of which may be, that the combination between the mercury and ſulphur is by this abundant acid ſo prevented or retarded, that the heat and motion requiſite to effect the converſion of acid into gas are not produced.

It appears then from Mr. *Bayen's* experiments that not only the nitrous acid but alſo the *marine acid* is *capable of detonation*, and, according to the above conjectures, of being *converted into Gas*.

CHAP.

CHAP. XIV.

Of Gas obtained by reducing metallic Calxes.

95. IT has been long observed by Metallurgists that *metallic calxes* suffered a *diminution of weight* by their *revival* or reduction to a metallic state; and that this reduction was always accompanied with effervescence, or disengagement of an elastic fluid. Mr. *Boyle* found that *minium* by being exposed to the focus of a burning glass in vessels open or hermetically sealed lost considerably of its weight; and he also observed that when the operation was continued, such a quantity of elastic fluid was produced, that the close vessels burst. *Boyle's Works, IV.* 149.

Dr. *Hales* obtained a gas by distilling *lead* and *minium* in a gun-barrel. (*Analysis of air*). Dr. *Priestly* and M. *Lavoisier* have also obtained elastic fluids from *minium* merely by application of a heat not more intense than was communicated by the flame of a candle applied to the phial containing the minium.

Dr. *Priestly* observed that much gas was produced during the revival of a calx of lead by the *electric spark*. (*Observ. and Exper. I.* 192.)

M. *Lavoisier* reduced two gros of minium, by adding twelve grains of charcoal previously well burnt in a close vessel, and exposing the mixture to the

the focus of a lens; and thus he obtained fourteen cubic inches of gas. (*Opuſcul. I.* 258.)

96. The gas obtained by reducing metallic calxes occaſions a precipitation in *lime water*, *extinguiſhes flame*, and is *noxious to animals*. M. *Lavoiſier* conſiders it as of the ſame kind as the gas of calcareous ſubſtances, with this difference only, that it contains a larger portion of common air. (*Opuſc. I.* 319.) His experiments induced him to believe that, in the reduction of minium by means of charcoal, a quantity of *water* is diſengaged from the metallic calx. *Ibid.* 270.

97. It has been obſerved (§ 14.) that metals during their calcination acquire weight, and that this acquired weight probably proceeds from ſome part of the air abſorbed. The reverſe ſeems to happen in their reduction; the metallic bodies then loſing their acquired weight, together with that matter which they received during calcination, and which ſeems to eſcape from them in form of gas.

C H A P. XV.

Of Alkaline Gas.

98. NOT only the vapour of acids but alſo that of *volatile alkali* may be raiſed into a permanent gas by means of heat, as Dr. *Prieſtly* has found. Thus by applying the flame of a candle to a phial containing volatile ſpirit of ſal ammoniac, he expelled much vapour, which being received into a veſſel

veſſel filled with quickſilver, continued uncondenſed by cold. When mild volatile alkali was employed, he obſerved that much of the gas which combines with alkaline and calcareous ſubſtances was alſo expelled. He therefore preferred the cauſtic volatile alkali, for the purpoſe of obtaining this alkaline gas. (*Experim. and obſerv. I.* 163, *&c.*)

99. Alkaline gas is very readily and copiouſly *abſorbed by water*, with which it forms a very ſtrong volatile alkaline ſpirit. It alſo *diſſolves ice* as faſt, as if the ice were expoſed to a hot fire. This gas *unites with the acid gaſes*, forming concrete ammoniacal ſalts; and with the *gas of calcareous ſubſtances*, with which it concretes into oblong ſlender cryſtals.

100. *Cygna* ſays that air ſaturated with volatile alkali is *inflammable*. Dr. *Prieſtly* alſo obſerved the ſame property in alkaline gas when mixed with air.

Alkaline gas was increaſed in its dimenſions by *electric ſparks* paſſing through it; and when as much of the gas was abſorbed by water as could be done, the reſiduum was inflammable. (*Prieſtly II.* 240.)

CHAP. XVI.

Of various Gaſes not deſcribed in the preceding chapters.

101. BESIDES the Gaſes deſcribed in the preceding chapters, ſome are mentioned by authors, and probably many remain not yet diſcovered.

Dr. *Hales* obtained Gaſes from *nitre*, *vitriol*, and *ſea-ſalt*, mixed with calcined bones and expoſed to fire;

fire; and also from *coals, clay, spar,* and *selenites.* (*Statics.*)

Dr. *Priestly* observes that a Gas which has the properties of that obtained from calcareous substances may be expelled by heat from several *saline* matters, as green, blue, and white *Vitriols,* calcined *alum, vitriolated tartar,* calcined *borax,* and *white-lead.* (*Expts. and obser. II.* 112. &c.

M. *Krenger* obtained an elastic fluid which united with, and crystallized a solution of fixed alkali, by distilling a *greenish fusible spar,* which was luminous in the dark: and he also affirms that a large proportion of a Gas which crystallized fixed alkali, has been obtained from a *white lead-ore* by M. *Sage.*

Dr. Priestly has obtained an acid Gas by distilling the minerals called *Fluors* with oil of vitriol, as in the process for obtaining the acid of Fluors; [*See Dictionary of Chemistry, Article Fluors.*] And he has observed the following properties of this Gas. *Exp. and Observ II.* 187. and *III.* 285.

This acid vapour or Gas no sooner came into contact with water than part of it was absorbed, and at the same time the surface of the water became covered with a *stoney film,* similar to that produced by the mixture of the acid of Fluors with water, and which Mr. *Scheele* pretends to be a *quartz* or *flint.* When this film was broken another crust was formed on the surface of the water, and so on successively till the whole of the Gas was absorbed by the water, which thereby becomes impregnated with a very volatile acid. As this acid is so readily absorbed by water, it requires to be confined in quicksilver.

This Gas retains its acid properties; for besides its uniting so readily with water, it forms a cloud with

alkaline

alkaline Gas, and it may be absorbed by chalk, from which it extricates calcareous Gas.

This Gas was *absorbed* by *charcoal*, by *rust of iron*, and by *alum*, the surface of which it rendered white and opake by seizing the watery part of the alum. When *salt-petre* was exposed to it, the vessel became filled with red fumes, and the Gas was gradually diminished till only one tenth part of it remained. One fourth part of this residuum was absorbed by lime-water, in which it occasioned a precipitation.

Water impregnated repeatedly with this acid Gas, and freed from the earthy crust, being heated, was found to yield a Gas which did not form any crust with water, but possessed all the properties which have been observed of Vitriolic acid Gas.

From the above properties of this Fluor acid Gas, Dr. *Priestly* is induced to think that the *fluor acid* is *not a particular acid*, but is the *acid of vitriol*, charged with as much phlogiston as is necessary to give it the form of Gas, and also with much of the earthy matter of the Fluor. And he is confirmed in this opinion from the following observations.

1. That Fluors contain phlogiston appears evident from the effects of distilling them with nitrous acid; by which means nitrous Gas, and a Gas capable of producing a precipitation in lime water, are formed.

2. It appears no less evident than an earthy matter is raised along with this Gas, from the crust which is precipitated from the Gas, when water is added.

3. The Gas obtained by applying heat to the water impregnated with fluor acid gas, possesses all the known properties of vitriolic acid gas; the water having deprived the acid of the earthy matter which gave to it the peculiar properties of the Fluor acid.

CHAP-

CHAP. XVII.

Conjectures and Speculations concerning the Theory of Gases.

102. WE daily see the same bodies assume very different appearances or states, under different circumstances: And of such changes no instances can be adduced more curious and surprizing than those which we have described concerning the formation of the various kinds of permanently elastic fluids. We have seen that solid, hard, and dense bodies lose at once their cohesion, acqnire a repelling force, and suddenly expand into a space many hundred or thousand times greater than that which they before occupied; forming rare, invisible, elastic fluids. We have also seen that the most expansive fluids can be again restored to a concrete state, and may conduce to the formation of very hard and solid bodies.

To explain these changes, exceeds, I fear, the limits of our present physical knowledge. Conjectures however may be admitted; which as they are not intended to decide, do not establish or confirm errors, but may be useful by suggesting certain questions to be ascertained by future experiments. With this view then only we proceed to the following speculations.

103. Many well known facts shew that matter is endowed with two contrary qualities, an *attractive* and a *repulsive power*, of which sometimes one, and sometimes the other exerts itself in different circumstances. Natural Philosophers have observed that the particles of bodies attract each other within certain distances; and that, when they are placed beyond the sphere of each other's attraction, they begin to exert a repulsive power. In order therefore to change a cohering concrete body into a repelling fluid or Gas, is it not sufficient that the particles of that body be removed to a distance from each other greater than the sphere of their attraction, that their repulsive force may begin to act? †

May not *Heat*, which is known to expand all bodies to such distances from each other, that their attraction

† Thus *Sir Isaac Newton* says, (*Optics*, *Quer.* 31.) "As in "Algebra, where affirmative quantities vanish and cease, there negative ones begin; so in mechanics, where *attraction* ceases, "there a *repulsive* virtue ought to succeed. And that there is such "a virtue seems to follow from the reflexions and inflexions of the "rays of light. For the rays are expelled by bodies in both "these cases, without the immediate contact of the reflecting or "inflecting body. It seems also to follow from the emission of "light; the ray so soon as it is shaken off from a shining body by "the vibrating motion of the parts of the body, and gets beyond "the reach of attraction, being driven away with exceeding great "velocity. For that force which is sufficient to turn it back in "reflexion may be sufficient to emit it. It seems also to follow from "the production of air and vapour. The particles when they are "shaken off from bodies by heat or fermentation so soon as they are "beyond the reach of the attraction of the body, receding from "it, and also from one another with great strength, and keeping "at a distance, so as sometimes to take up above a million of times "more space than they did before in the form of a dense body."

traction shall cease, and their repulsion commence? And is not this the mode of action by which Heat raises Water, Mercury, and other volatile bodies into elastic vapours; some of which by cold are again brought within the sphere of each others attraction and condensed; while others, possessed of a stronger repulsive power, remain in an expanded state, forming some of the permanently elastic fluids called Gases?

104. May not also a *violent motion* or *quick vibration* excited among the minute particles of bodies occasion a similar separation of these particles, and a consequent change from a concrete to a repelling state? Thus the particles of fire and light are supposed by *Sir Isaac Newton* to be thrown off from ignited or luminous bodies by the motion and vibration of their parts. May not also the violent intestine motion excited in the particles of bodies during their *decomposition* and *solution by menstruums*, as of *metals by acids*; and also of bodies undergoing the *vinous*, *putrefactive*, or *other fermentations*, produce in the same manner the gases which are known to be formed in these several operations? For when any two united particles are torn asunder by the superior attraction or affinity of a menstruum or solvent, must they not at the instant of separation recede from each other with a force equal to that with which their disjunction was resisted; in the same manner, as the two parts of a cord, stretched till it breaks, recoil towards the opposite points of tension. And the effect of the violent separations of the particles of bodies which occur in chemical decompositions, solutions, and fermentations will appear very great, when we consider the *minuteness* of the particles engaged in these operations, and

how much the activity or force of the attraction and repulsion of bodies depends on the minuteness of their size. For, it is known that the attraction of any two bodies to each other encreases as the distance between them decreases, in some high ratio: And as the distance at which all the particles of any body can exert their attractive power upon any other contiguous body, may be supposed equal to the semi-diameter of the attracting body; therefore the particles of large bodies must exert that power at a greater distance than those of smaller bodies, and consequently the attractive force of large bodies must be less than that of smaller bodies, in proportion to the quantity of matter contained in each.

105. Some bodies are more disposed than others to be changed from a concrete to an elastic state. Those which cohere with least force, will most easily have their particles thrown out of the sphere of each others attraction. And this seems to be the case with all those bodies which are called *volatile*, as water, spirit of wine, and ether. And is not even the *evaporation* of cold water and of some other volatile liquids, especially in vacuo, occasioned by some of the particles, at the surfaces of these liquids, where they are not compressed by other particles, being thrown by the agitation, which continually prevails in fluid bodies, to such distances, that their repulsive force can begin to exert itself?

But bodies which are easily expanded to an elastic state, are also easily reducible to their former state, and are generally condensable by cold into the same species of bodies as they were before their volatilization. For, as their cohesive power is weak, so also is their repulsive power; and therefore cold, which approximates

mates the particles of bodies, is capable of bringing them again within the ſphere of each other's attraction.

But bodies, on the other hand, whoſe parts cohere ſtrongly, and which therefore cannot be disjoined without violent efforts, ſuch as thoſe which produce the ſolution and decompoſition of bodies, whether by heat, by acid menſtruums, or by fermentations, form elaſtic fluids, whoſe repulſive power is ſtronger, and which cannot be condenſed merely by cold. The violence of the effort employed in theſe operations appears from the heat with which they are accompanied, and which is very conſiderable, notwithſtanding the large quantity of matter to which that heat is generally communicated in proportion to the quantity of acting particles. From ſuch bodies therefore are chiefly formed the uncondenſable fluids called *Gaſes*. †

106. Of all the concrete bodies which we know, none poſſeſs ſo ſtrong and general an attractive power as *acids* do. For they are known to unite and combine with water, oils, earths, and metals. Nor do perhaps,

† "The particles of fluids which do not cohere too ſtrongly "and are of ſuch a ſmallneſs as renders them moſt ſuſceptible of "theſe agitations which keep liquors in a fluor, are moſt eaſily ſeparated and rarefied into vapour, and in the language of chemiſts "are volatile, rarefying with an eaſy heat, and condenſing with "cold. But thoſe which are groſſer and ſo leſs ſuſceptible of agitation, or cohere by a ſtronger attraction, are not ſeparated "without a ſtronger heat, or perhaps not without fermentation. "And theſe laſt are the bodies which the chemiſts call fixed, and "being rarefied by fermentation, become true permanent air. Thoſe "particles receding from one another with the greateſt force, and "being moſt difficultly brought together, which upon contact co- "here moſt ſtrongly." *Newton's Optics, Quer.* 31.

haps any bodies resist their action, excepting those compounds which are already saturated with acid, as sulphur is. When we consider the great activity of acids, and also how much the activity of bodies depend on the minuteness of their particles, does it not seem probable that the particles of acids are very minute, and that to this minuteness of size, these bodies owe their strong attractive dissolving power.

107. There is another body which never appears to us in a concrete state, unless when combined with other substances, but which seems strongly disposed to unite with every other class of bodies, excepting perhaps water, with which it does not appear to be capable of combining, but by the intervention of acids. This is the *matter of light*; those minute particles which have been repelled from the surface of the sun, and other ignited bodies; and are absorbed and combined with acids, and earths, forming the various combustible matters, vegetable, animal, and mineral. †

These matters it endows with the property of inflammability, and hence it is called by Chemists, *Phlogiston*.

Now the amazing tenuity of the matter of light is well known; and from this property perhaps arises its extreme susceptibility of that motion on which heat depends, and the violence with which it combines with those substances which it most strongly attracts. From this susceptibility of motion, must not the particles

† "Are not *gross bodies* and *light* convertible into one another, "and may not bodies receive much of their activity from the particles of light which enter their composition?" *Newton's Optics*, *Quer.* 30.

ticles of this matter of light be peculiarly disposed to be agitated and thrown from the sphere of each others attraction, and to exert the repulsive faculty. Accordingly, not only light itself possesses eminently this repulsive faculty, but also the substances with which this matter is combined are thereby rendered more volatile, as numberless chemical facts demonstrate.

Acids then and the matter of light seem to be substances, very capable of being converted by heat and motion from a concrete to an elastic or repellent state, and of forming permanent gases. They are also more disposed to unite and combine with each other than with any other matter. And accordingly we shall find upon examination of the preceding history of gases, that in the formation of almost all of them, an acid and phlogiston enter into the composition of the substances employed. May we not then infer that most of the known gases principally consist of these two matters; and that the differences between these elastic fluids arise from the diversity of acids, the proportions of the component matters, the modes of combination, and the various other substances, as earth or water, which may have been originally combined with the acid and phlogiston in their concrete state, and may have *adhered* to them in their expanded state, or have entered as essential parts into the *composition* of the several gases?

As this inference is important in the theory of gases, let us consider on what grounds it is established, and examine more particularly the constitution of the several permanently elastic fluids described in the preceding chapters.

108. We have seen that the vitriolic, nitrous and marine acids, may, when united with any inflammable

matter be converted by heat into those gases which we have called *acid*, because they seem to retain their acid properties, of acting upon the metallic, alkaline, and other substances, with which they combine when in a liquid state: and also, of uniting readily with water, by which they are reduced to their original state of liquid acid. As these vapours are not condensable by common cold, they have been considered as gases; but from their easy reduction to their former concrete state, and their retaining their acid properties, while in their expanded state, they seem to be of the more imperfect kind of those fluids. We may observe, that these gases are not formed from any violent action, intestine motion, or decomposition of bodies, but that they are raised merely as vapours are, by moderate heat. Are not then these gases formed of acids volatilized by means of water and phlogiston? Does not the acid part greatly predominate over the phlogistic in their composition; and is not the phlogiston in a very imperfect state of combination with the acid, because this acid is united with much water, and water does not easily combine with phlogiston? And do not the acid properties of these gases depend on this imperfect combination with phlostiston, and on the predominancy of acid in their composition?

110. We have seen that the vapour raised from *volatile alkali* was found to be not condensable by the cold of the atmosphere; and we have described it, as we have done the above-mentioned acid vapours, under the name of Gas. But we may observe of both acid and alkaline vapours, that if, upon further examination, they be found not condensable by any cold which we can apply to them, and be therefore comprehended under the definition of Gas given in chap. 1, they

they muſt be allowed to be of the moſt imperfect kind of gaſes. For neither the acid or alkaline vapours can be conſidered as compounds formed, during their expanſion into an elaſtic ſtate, from decompoſed and violently ſeparated parts, but are the mere entire vapours of the bodies from which they are raiſed, retaining, while in their elaſtic ſtate, the properties of theſe bodies; and capable of being reduced, when condenſed by water, into concretes or bodies ſimilar to thoſe from which they were formed.

As to the conſtitution of this alkaline vapour, it may ſeem to afford an exception to the propoſition above mentioned, that the known gaſes principally conſiſt of acid and phlogiſton. But, beſides that alkalis themſelves are believed by Chemiſts to conſiſt of earths imperfectly ſaturated with acid and phlogiſton; this exception cannot be admitted, till the permanency of the elaſticity of this vapour, and its claim to the ſtate of gas be aſcertained. At the ſame time however that I attempt to ſhew that moſt of the gaſes now known, conſiſts principally of acid and phlogiſton, I admit the probability, that phlogiſton may be formed into a gas with any other ſubſtance, with which it is capable of uniting, as with earth. That phlogiſton may unite merely with earths, appears from the inſtance of metals; if the received theory of theſe bodies be juſt. The alkaline vapour therefore, if it be really a gas, may be one of this kind, conſiſting chiefly of earth and phlogiſton. The *inflamable gaſes* produced from metals alone merely by heat, (§77.) are alſo probably of this kind, conſiſting of the ſame component parts as the metals themſelves, that is, of earth and phlogiſton, but differently proportioned, the earth being predominant in the me-

tals, and the phlogiston in the gases. That the phlogiston of these gases is not pure and uncombined, we may infer from its not being seized upon by the air as soon as these fluids come into contact; whereas heat and even ignition are required, for the decomposition of this, as of the other inflammable gases.

111. We have seen that *Inflammable Gases* are formed from the vitriolic or marine acids acting on iron, zinc, or tin; from marine acid gas acting upon these metals, or upon almost any inflammable substance; from many inflammable compounds, by means of heat, as from coals, vegetable, and animal substances, during the decomposition of these compounds; and from animal or vegetable matters undergoing the putrefactive fermentation.

In all these different kinds of inflammable gas, we may perceive that acids and inflammable matter are the principal ingredients, not only in the metallic solutions, in which the acid unites with the phlogiston of the metals; but also in the vegetable and animal matters, by the analysis, or by the putrefaction of which, inflammable gases are produced. For, in these the vegetable and animal acids abound; and from the inflammability of these matters, it appears that the acids are combined with phlogiston. The conversion of the marine acid gas into inflammable gas by the action of that acid vapour on phlogistic substances, sufficiently shews the constitution of this inflammable gas. The inflammability also of the disengaged vapour of hepar of sulphur can scarcely be supposed to arise from any other matter than phlogiston and acid.

Do not then these inflammable gases consist chiefly of acids and phlogiston; as indeed all other inflammable matters do, excepting perhaps the calcinable

metls,

metals, in which the phlogiſton ſeems combined with earths, although in metals alſo a latent acid has been ſuſpected by ſome chemiſts ?

We have remarked, (§. 105.) that the moſt perfect gaſes are formed by a violent ſeparation of parts. Now, in all the modes of forming inflammable gas, the ſubſtances are decompoſed, and their parts violently torn aſunder. The quantity alſo, and inflammability of this gas are greater, when the heat is ſuddenly applied, or when the ſolution proceeds with violence. And accordingly, the properties of this gas indicate it to be of the moſt perfect kind. For, it is the rareſt, the moſt immiſcible with water, of any known gaſes. Theſe properties probably proceed from the phlogiſton which ſeems to abound in this gas, or at leaſt perfectly to ſaturate the acid in its compoſition. Hence it may be conſidered as a true elaſtic fluid ſulphur. If it ſhould be objected, that the ſaturation of the vitriolic acid with phlogiſton ought to conſtitute a concrete ſulphur and not a gas; the anſwer may be, that either ſome third ingredient as earth may perha s enter into the compoſition of this gas ; or, that the proportion of vitriolic acid and phlogiſton requiſite to form ſulphur is probably very different from the proportion requiſite to form inflammable gas. For we may obſerve, that there are generally two modes of combination inwhich two ſubſtances can unite. Thus when equal quantities of Ether and Water are mixed, two diſtinct compounds are formed, in one of which the Ether, and in the other, the Water is predominant. The former compound may be ſaid to be Ether ſaturated with Water ; and the latter, water ſaturated with Ether. In a ſimilar manner, I conjecture that common concrete Sulphur conſiſts of vitriolic

acid

acid saturated with phlogiſton; that the inflammable gas conſiſts of phlogiſton ſaturated with acid; and that the *acid gaſes* conſiſt of acids ſaturated with water, and with as much phlogiſton as this compound of acid and water can admit; which quantity of phlogiſton I ſuppoſe to be ſo ſmall that it is barely ſufficient to raiſe the other fixed matters into the form of the gas, without being able to ſuppreſs the activity of the acid on other bodies.

Iron, zinc, and tin are the metals from which inflammable gaſes are moſt eaſily produced: and the reaſon ſeems to be, that theſe metals, when diſſolved by acids, do moſt eaſily part with their phlogiſton; as chemiſts have often obſerved.

112. We have ſeen that inflammable gaſes have been formed from the vitriolic, the marine, the vegetable, and the animal acids. But no method has been yet diſcovered of making a perfect inflammable gas, by means of the nitrous acid; although we have ſeen ſome approaches towards it. §.63.*e.* Nevertheleſs, the *nitrous gas* deſcribed in chap. 10 ſeems to be ſomewhat analogous in its compoſition to inflammable gaſes. For it is formed from the nitrous acid acting upon metallic and phlogiſtic ſubſtances; and the combination of phlogiſton with the acid ſeems to be ſo intimate, that it ſupreſſes the peculiar qualities of the acid; for this gas does not act as an acid upon metals or other ſubſtances; neither does it very readily mix with water, without the contact of air; and even when abſorbed by water, it does not communicate its acid qualities to this fluid, till the water has been expoſed to air, which decompoſes the gas, and diſengages its acid, as Mr. *Bewley* has well obſerved. The phlogiſton however in this gas does not ſeem to be

be so perfectly combined, as it is in the inflammable gases; for the following reasons. 1. This gas is considerable denser, being, as Dr. *Priestly* thinks, † as heavy as common air is; whereas inflammable gas is greatly lighter. 2. It mixes more readily with water than inflammable gas does. 3. It parts with its phlogiston more easily; for, no sooner does common air come in contact with this nitrous gas, than the phlogiston seems to pass from the latter to the former; and the acid thus deprived of the substance to which it owed its elastic state, is changed into a liquid concrete or spirit of nitre. Although therefore nitrous gas does not inflame, it appears to undergo a process similar to that of inflammation, namely, a separation of its phlogiston by means of common air: And the difference seems to be, that the phlogiston is so firmly combined in the inflammable gases, that it cannot be separated from its acid by the superior attraction of the acid of the air, till its activity has been encreased by ignition; whereas it is so much less perfectly combined with the acid in the nitrous gas, that it is separated immediately upon mixture with common air. Chemistry furnishes many instances of two compounds consisting of similar ingredients, or even of the same ingredients differently proportioned, in one of which a decomposition may be effected by a given substance without heat, and in the other only by means of heat. Thus sulphur which is a compound of vitriolic acid and phlogiston cannot be decompounded by nitre without ignition; whereas volatile sulphureous acid, which also consists of vitriolic acid and phlogiston together with water, may be dephlogisticated by nitre with little or no heat.

Perhaps

† Priestly. exper. and observ. I. 119.

Perhaps the reason of the combination of the two principal component parts in nitrous gas being less perfect in this than in inflammable gas, may be, that in the former gas a larger portion of water may adhere to the acid, and prevent the intimacy of the combination of the acid with the phlogiston.

If this conjecture be just, the nitrous gas seems to be in an intermediate state between the acid and the inflammable gases.

113. All those Gases, which occasions a *precipitation in lime-water*, have been generally comprehended under one class, and distinguished by the name of *Fixed Air*. We have seen that they are produced from many different materials; 1. From calcareous, and from alkaline substances, by acids, or by fire: 2. From any combustible animal or vegetable matters, when decomposed by fire, or by concentrated acids; 3. From animal and vegetable matters underoing the vinous and other fermentations; 4. From metallic calxes by reduction, and sometimes merely by heat; as from minium; 5. From some metallic and other salts, as green vitriol, by fire; 6. From air decomposed by electricity; 7. From the deflagration of nitre; and in the various processes in which the nitrous acid is used to produce gases; 8. From subterranean pits and caverns; 9. From mineral waters; and probably, they may be obtained from many other substances. So many instances occur of this gas being produced in processes where the nitrous acid is employed, as in all those for obtaining deflagrating air, and nitrous gas (excepting where this is produced by means of metals) that Dr. *Priestly* is inclined to think that this gas is a modification of the nitrous acid, together with some portion

portion of phlogiſton and earth. *Exper. and obſ. III.* 28.

But the variety of ſubſtances which yield theſe gaſes capable of precipitating the earth diſſolved in lime-water, is ſufficient to create a ſuſpicion that there may be conſiderable differences among them. Perhaps, in all theſe gaſes, the ſame mode of combination prevails, although the acids which enter into their compoſition be different. From the above enumeration of the various modes of production, almoſt any acid ſeems capable of aſſuming this ſtate. But the animal and vegetable acids appear to be peculiarly diſpoſed to form this gas. For, we find from the experiments of Dr. *Hales* that a very large proportion of the vegetable eſſential ſalts, as tartar, were converted into a gas of this kind; when theſe ſaline ſubſtances were decompoſed by fire. In this operation, the acid diſappears, and a gas is produced. For, no gas exiſts in the tartar, or other vegetable body, till it be decompoſed; the gas being a peculiar compound formed, during the decompoſition of the vegetable matters, by fire, or by fermentation. Thus when tartar is united with fixed alkali, as in making Rochelle ſalt, the alkali, if cauſtic, is not rendered mild; and, on the contrary, if mild, it's gas will be expelled by the tartar, as it would by any other acid. But, if this compound of tartar and cauſtic alkali, in which no gas exiſts, be burnt, the alkali remaining will be mild and efferveſcent; for the acid of the tartar being decompoſed by the fire, and formed into a gas, a part of it will unite with the alkaline reſiduum. And if *ſoap*, which conſiſts of cauſtic alkali and oil, be burnt, the alkali will be rendered mild, by

by the gas formed from the acid, which is known to be a conſtituent part of oil. Alſo, if nitre be deflagrated with any animal or vegetable matter, the alkaline baſis of the nitre, which is cauſtic, while combined with the nitrous acid, will be rendered mild; whereas, if nitre be deflagrated with zinc or tin, which metals contain no acid capable of converſion into gas, the alkaline reſiduum will be cauſtic. †

Is not the gas, which, in the above inſtances, renders the cauſtic alkalis mild, the reſult of ſome combination principally of acid and phlogiſton; both which ſubſtances are known to be contained in all undecompoſed vegetable and animal matters? This compound however, ſeems to be ready formed, or nearly ſo, in all native calcareous bodies; and nothing is required, but the action of any acid, to diſengage it from theſe bodies, and to give to it the elaſtic ſtate of gas. Does not the gas of theſe bodies proceed from ſome ſmall portion of animal acid and phlogiſton adhering to marine ſhells and other animal reliques; for ſuch all calcareous bodies probably have been? And what are the natural changes which have effected that peculiar combination, which in all other inſtances, requires the aid of fire, or of concentrated acids, or of fermentation?

The exiſtence of an acid, as a principal conſtituent and even as the predominant part of this gas is indicated by ſeveral of its properties. For it acts upon and diſſolves ſeveral earthy and metallic ſubſtances; it

† The production of a mild alkali by deflagration of nitre with charcoal, and of a cauſtic alkali by deflagration of nitre with filings of zinc or of iron, has been alſo noticed by Mr. *Bewly*. *Appendix to Dr. Prieſtly's third Vol. of Exper. and Obſerv. p.* 387.

it unites with alkalis and calcareous earths, and it effects their cryſtallization, as other acids do; it may be diſengaged from theſe alkaline ſubſtances by ſtronger acids; it has been found to change the blue colour of the juices of turnſole, of litmus, and of cyanus to red; ‡ and it gives an acid taſte to the water which it impregnates.

The acid quality however of this gas is very weak, being counteracted by its combination with phlogiſton, which in many inſtances is known to leſſen or deſtroy the activity of acids, and which, as we have conjectured, is a neceſſary conſtituent part of every gas. The quantity of phlogiſton in this gas, although ſufficient to weaken its acidity does not however ſeem to be conſiderable; for the gas retains much of its acid quality; it is pretty readily abſorbed by water; and it has a greater denſity than ſome of the other more perfect gaſes. Theſe reaſons alſo render it not improbable, that ſome portion of water may adhere to the acid, in the compoſition of this gas. †

114. Of all the gaſes *Air* being of the greateſt importance to us, has been moſt attentively examined by Philoſophers:

‡ Dr. Prieſtly's exper. and obſ. Vol. I. 31. and Appendix to vol. II. by Mr. Bewley.

† *Signor Fontana*, in a treatiſe entitled, *Ricerche Fiſiche ſopra l'aria fiſſa*, attributes the acidity of the gas extracted from calcareous ſubſtances by means of oil of vitriol, to the acid employed, which he thinks may be diſſolved in this gas, as water is diſſolved in air, ſo intimately that neither water nor alkali can ſeparate this acid; and he thinks that to this volatalized and combined vitriolic acid, the fixed air owes its medicinal qualities, the acid being thus rendered more efficacious than in its proper uncombined ſtate. And alſo *Signor Landriani*, in his *Ricerche Fiſiche intorno allo ſalubrita dell'aria*, maintains that the acidity of this gas proceeds from the acid

Philoſophers: a knowledge however of its conſtitution, and of the mode of operation by which its ſingular effects are produced, has nevertheleſs eluded their inquiries. The exiſtence of an acid, and even of the nitrous acid in air, has indeed been ſuſpected chiefly from the neceſſity of air, towards the formation of nitre, and from the analogous effects of nitre and of air in promoting inflammation. But, no experiments have been ever adduced to give ſuch ſolidity to this conjecture, as thoſe of Dr. *Prieſtly*, which ſhew that a fluid reſembling air in all its known properties, and even poſeſſing the peculiar properties of air in a much more eminent degree than the atmoſpherical air itſelf does, may be produced from nitrous acid mixed with almoſt any unphlogiſticated earth. If therefore it be admitted that nitrous acid is one of the principal component parts of air, as theſe experiments ſeem to indicate, we have advanced a conſiderable ſtep towards a knowledge of the conſtitution of the atmoſpherical fluid. That phlogiſton enters into the compoſition of the gaſes above deſcribed, can ſcarcely be doubted. It ſeems even to be eſſential in the formation of theſe compounds. Neither can we doubt that ſome portion of phlogiſton is contained in air; eſpecially if we admit that phlogiſton is a conſtituent part of the nitrous acid itſelf, as our beſt theoretical chemiſts maintain.

acid employed in the operation of extricating it, and that when this gas is mixed with vapour of volatile alkali, an ammonical ſalt will be formed, which will be found to be a vitriolic ammoniac, if the acid employed had been the vitriolic, and a deflagrating nitrous ammoniac, if nitrous acid had been employed. Mr. *Bewley*, in the Appendix to Dr. Prieſtly's ſecond volume of experiments and obſervations, very well defends the opinion of the intrinſic acidity of this gas, and ſhews that the ſame indications of acidity are exhibited by gaſes extricated from volatile alkali and from magneſia, by heat, and without intervention of any foreign acid.

tain: Perhaps, indeed, no more phlogiston enters into the composition of air than is contained in the nitrous acid; and this portion may be sufficient for the purpose of forming air, when the necessary degree of heat is applied. For, when any phlogistic substance is added to nitrous acid, and heat is applied to the mixture, not air, but other combinations, as the nitrous gas, and the gas which occasions a precipitation in lime-water, are produced. Perhaps then, air may be nothing else than nitrous acid converted into the state of gas; and the earths employed in the process for making deflagrating air, may be only useful, by communicating a more intense heat, than can be given to the acid alone: for, this acid, when alone, can be evaporated with a very moderate heat; but, when mixed with certain earthy substances, its adhesion to these may be such, that it may bear a much greater degree of heat, before it be converted into vapour; and this degree may be sufficient for the purpose of forming it into gas. Perhaps, indeed, in the violent separation of the acid from the earth, some portion of the latter may adhere, and even be a necessary part in the combination of air. *

* Dr. Priestly is induced to think from his experiments that air is compounded of nitrous acid and earth, and even that the greatest part of it consists of the latter substance. III. 42. He has made some experiments to ascertain the proportion of nitrous acid contained in the deflagrating air made from spirit of nitre and earth; but he does not consider them to be decisive. The question is important but seems difficult of solution. The *Abbe Fontana* maintains that this deflagrating air consists of spirit of nitre only, without earth or phlogiston; and he supports his opinion by the following experiments. He converted a given quantity of mercury into red precipitate; and he expelled from this preparation

So far then it seems *probable*, that air is a compound body, consisting chiefly of the nitrous acid; and Dr. *Priestly*'s experiments have *ascertained* the possibility of a *similar* fluid being formed from that acid. Nevertheless, it must be confessed, that the proof of the nitrous acid being a component part of atmospherical air cannot be considered as compleat, till we can shew a method of obtaining nitrous acid from air without the intervention of substances containing the animal and vegetable acids. For, while these substances are employed in the compositions for producing nitre, a suspicion may remain of the convertibility of these acids into the nitrous. And although we admit, that the same properties, so far as we have examined them, may be found in the atmospherical air, and in the air produced by means of the nitrous acid; yet I doubt whether we can with certainty infer, that the same acid enters into the composition of these two airs. For, a very strong resemblance between two compounds may

as much air as he could. Then he revived the mercury of the remaining precipitate, and found that the quantity obtained was equal to the quantity of mercury originally employed. Dr. Priestly has repeated the experiment; and found that there was a loss of about 1-11th part of the employed mercury: And Mr. Magellan, repeating the same experiment, lost about 1-3d of the mercury. It appears then there must have been some error in the Abbé's experiments; but the experiments of Dr. Priestly and of Mr. Magellan are not applied by these gentlemen to ascertain the quantity of earth actually converted into air; neither do I think that they *prove*, that any earth enters into the composition of the air; for in all the productions of air by heat, the rising air elevates a great deal of earth mechanically, or by trusion, from the earthy substances in the retort; and this earth, not being dissolved, but only suspended in the air, renders the air turbid, gives the appearance of white clouds, and at last subsides.

may arise from the similarity of the combination, although a component part of one compound may be of a different species from the analogous component part in the other compound. Thus we have seen that inflammable gases, similar in their properties, so far as we have examined them, consist of very different acids, the vitriolic, the marine, the vegetable, and the animal. And we have also seen that those gases, which, from their similarity of properties hitherto discovered, have been considered as being of the same kind, and distinguished by the same name, *Fixed air*, are similar compounds, consisting of very different acids.

The question then seems to remain undecided, whether the acid of the air and of nitre be precisely the same. Perhaps indeed the differences of acids themselves may depend merely on some difference of combination, and that the acid part is universally the same in all, according to the doctrine advanced by *Stahl*, and maintained by many chemists. Much elucidation may be expected upon this subject from Mr. *Lavoisier*, who has announced a Treatise on the *total decomposition of three mineral acids*; and from Mr. *Woulfe*, who (as Dr. Priestly informs us) † has discovered methods of converting marine acid into the nitrous, and of converting nitrous acid into the marine. But if the species of acid contained in the air be not compleatly ascertained, we cannot doubt that some acid is one of the principal constitutent parts of this fluid, as well as of the several gases above mentioned: And we must at the same time admit the

 greater

† Exper. and observ. vol. II. 161.

greater probability of this acid being the nitrous than any other which we know. ‡

115. However imperfect our knowledge of the constitution of the atmosphere may seem; the explanation of

‡ The opinion which I have here maintained, that most of the known gases consist principally of acid and phlogiston, was suggested in the notes which I added to the first English Edition of the *Dictionary of Chemistry* published in 1771. Thus at the Article *Fixable Air* are the following passages. " Have not the fluids separable from alkaline and metallic substances some analogy with " *acids?* Like acids, they readily *unite* with, and effect the *crystallization* of those (alkaline) substances. As a *weaker* acid is " extricated from those substances by a *stronger*, so is this (fixable) " air by all known acids. Are not the elastic Fluids, produced by " the *Deflagration of Nitre*; and by the *combustion*, or *alkalization* " of *tartar*, and of other *vegetable acid salts*, formed from the *acids* " of these substances combined with the *inflammable principle?*" —— " A permanently elastic Fluid or fixable Air is produced by " *deflagration* of *nitrous acid* with any inflammable substance. In " this operation the acid disappears and an elastic vapour is produced. May we not thence infer, that the *acid* is *converted* by " combination with some other substance, probably with the *inflammable matter*, or by decomposition of its own substance, into " elastic vapour." (*vol. I. page* 36.) And in a note to the Article *Mineral Waters*, it is said; " Does not the *solution of calcareous earths* by fixable air confirm a conjecture concerning the analogy of this vapour with acids?" (*vol. II. p.* 838.) Since the publication of that work this opinion has been further confirmed by many of the new facts which have been discovered; and the acid quality of the Gas called *Fixed Air* has been noticed by other later writers. Thus *M. Bergman*, as Dr. Priestly informs us (*Exp. and Obs. Vol. I. p.* 31.) is induced from the effects of this gas on the colour of vegetable flowers, to consider it as an acid, and to call it the *Aerial acid*. And Mr. *William Bewley* has added an Appendix to Dr. Priestly's second volume, entitled, " Experiments and Observations tending to prove that Fixed Air is the vapour of a " *particular* acid." Mr. Bewley distinguishes this Fluid by the " name of *Mephitic Acid*.

of the singular properties of the air in maintaining fire and the respiration of animals, in diminishing nitrous gas, in calcining metals, and in being diminished by the various means already described, will be attended with more difficulty and obscurity. The way to truth, however, must be felt for, when it cannot be seen; and, accordingly, we proceed in our conjectures.

We may perceive, that almost all the chemical changes which happen to bodies are the result of decompositions, occasioned chiefly by the application of substances, whose attraction to some of the parts of these bodies is stronger than the attraction of the parts to each other. This general observation has been applied to explain the effects of air. It has been supposed that air, or its acid, have a stronger attraction to phlogiston than any other substance; and consequently, that, where any inflammable ignited body is exposed to air, the phlogiston leaves this body, and unites with the air.

The *deflagration of nitre* is also explained by supposing that the nitrous acid possesses an attraction to phlogiston superior to that of the parts of the inflammable body employed. And the *Detonation of Fulminating Gases* seems to proceed from the sudden conversion of acid, together probably with some phlogiston, into Gas, as has been already suggested. § 94.

The *calcination of metals* is considered by chemists as a slow combustion; and the air is supposed to operate in the same manner as in other combustions.

Respiration is represented by Dr. *Priestly* as a phlogistic process, in which the phlogiston, with which the animal system abounds, is discharged from the

blood

blood by the lungs, and combines with the air. (*Phil. Transf.*)

Dr. *Prieſtly* alſo conſiders the effects of *mixing nitrous gas with air* as a phlogiſtic proceſs, in which the air deprives the gas of its phlogiſton; and he ſuppoſes, that, in all thoſe inſtances where air is diminiſhed by liver of ſulphur and other phlogiſtic ſubſtances, the air attracts and combines with the phlogiſton of theſe ſubſtances, and becomes thereby phlogiſticated.

If it ſhould be aſked why the phlogiſton of inflammable bodies cannot be ſeparated without heat and even ignition; whereas this phlogiſton may be ſeparated from nitrous gas, from the blood in reſpiration, from liver of ſulphur and other phlogiſtic bodies, merely by contact of air; may we not anſwer, that, in the latter inſtances, the phlogiſton is but ſlightly attached, and eaſily ſeparated; whereas, in inflammable bodies, it is ſo intimately combined, that it cannot be ſeparated, till the parts of theſe bodies have been thrown into violent agitation by heat, their coheſion diminiſhed, the volatility and activity of the phlogiſton encreaſed, and its combination with air thus facilitated? And may not the intenſe heat, flame, and other effects of burning bodies, proceed from the agitation excited among their moſt active parts, from the violence with which they are torn aſunder from each other, and from the rapidity with which the minute and elaſtic particles of air and phlogiſton ruſh into union? For, in what does *heat* conſiſt, but in the exceedingly quick vibrations of the particles of burning bodies; or *light*, but in the extreme rapidity and force with which the moſt active particles are thrown from the ſurfaces of theſe bodies?

If it should be asked, why the air, which is said to be a combination of nitrous acid; or, at least, why deflagrating air, which is produced from that acid, should take phlogiston from nitrous gas, which is also formed principally from nitrous acid; may we not answer, that, although each of these fluids contain, in their composition, nitrous acid; yet they are very different combinations? For, if the nitrous gas contain, as has been above conjectured, a considerable portion of water in its composition, its attraction to phlogiston will be thereby so weakened, that air may be able to deprive it of this essential part to its elastic state; while the other parts in the composition of this nitrous gas, the acid and the water, shall be condensed and reduced to the state of liquid nitrous acid.

Whence proceeds the heat that is observed upon the mixture of nitrous gas with air? May it not be a necessary consequence of the condensation which instantly happens upon the mixture of these two fluids? For, is it not an universal rule, that cold is produced by the expansion of bodies into a rarer state; and heat by their condensation? Hence the cold produced during the evaporation of fluids, and during the rarefaction of air, by means of the air-pump; and hence the heat which is communicated by vapours during their condensation, which has been observed to be much greater than can be communicated by an equal quantity of any concrete matter heated to the same temperature.

Hence also the heat that is observed to accompany *Fogs* which are nothing but condensed vapours. Are not the other diminutions of air, and condensations of elastic fluids also accompanied with heat?

Whence

Whence proceeds the gas which is produced in combuſtion, and which is of the kind that occaſions a precipitation in lime-water? From the air itſelf, the more fixed and denſe part being precipitated, as Dr. *Prieſtly* is inclined to think; or from the burning body? We know that a gas of this kind may be obtained by analyſing any vegetable or animal inflammable ſubſtance. Charcoal indeed, when expoſed to ſolar heat in vacuo, was found by Dr. *Prieſtly* not to yield any gas. But this charcoal ſuffered no decompoſition; whereas by burning, the component parts of a body are ſeparated, and new combinations may take place. Perhaps then, this gas may be the reſult of a combination between the acid of the inflammable body and a ſufficient quantity of phlogiſton to form it into a gas of this kind. For, all combuſtible bodies, excepting metals, are compounds conſiſting of acid and phlogiſton, together with water and earth. Now, what becomes of the acid, while theſe bodies are burnt; for they are not to be found after combuſtion. excepting the very fixed acids of ſulphur and of phoſphorus? But is any gas formed during the combuſtion of theſe two ſubſtances? Certainly, when ſulphur is burnt, no precipitation is produced in lime-water. Dr. *Prieſtly* indeed attributes this effect to the precipitate being rediſſolved by the acid of the ſulphur. When ſpirit of wine, which appears to be a combination of vegetable acid with phlogiſton, is burnt under a bell, the vapour being condenſed and collected is found to be nothing but water; while a gas is produced capable of occaſioning a precipitation in lime-water. When metals are calcined, no gas of this kind appears. Is the reaſon, that metals contain no acid; or that the gas is ab-

ſorbed

sorbed by the calcining metal, as fast as it is precipitated from the air, as Dr. *Priestly* ingeniously alledges?

Whether this gas be precipitated from air; or be a compound formed from the decomposed parts of the burning substance; or lastly, whether some gas of this kind may not proceed from both these causes; we can scarcely doubt that some part of the air is separated, fixed and combined with the burning substance. This opinion is confirmed by the following experiment of M. *Lavoisier*.

He burnt some phosphorus under a bell, the inner surface of which was moistened with distilled water. The quantity of phosphorus employed was 186 grains. Of this quantity thirty two grains remained unconsumed; and therefore 154 grains were actually burnt. The vapours of the phosphoric acid being condensed by means of the water, with which the bell was moistened, were collected and weighed in a narrow necked vessel; by which means he found, that the weight of the acid liquor exceeded the weight of an equal bulk of distilled water 243 ½ grains, which was 89 ½ grains more than the quantity of phosphorus consumed. These 89 ½ grains could not be water attracted by the phosphoric acid, for the specific gravity of the liquor could not have been thereby encreased; and he therefore infers that this accession of matter must have proceeded from some part of the air absorbed during the combustion.

116. Does not the encrease of weight gained by *calcining metals* proceed from absorption of air, or part of air? And may we not attribute to this cause the *deflagrating airs* obtained by heat, from *minium* and from *calcined mercury*, and more abundantly from *mi-*

nium and *vitriolic acid*, as has been already ſhewn in chap. II. § 30? As the preparation of minium, and of calcined mercury, requires a longer expoſure to the action of fire and of air, than that of other *calxes*; theſe metallic matters may perhaps be more perfectly deprived of ſuperabundant phlogiſton, or may abſorb a greater quantity of air, than the calxes of other metals. And if the abſorbed air cannot be generally expelled from metallic calxes, by heat, or by ſtrong acids, may not the reaſon be, that its attraction to theſe calxes is ſo powerful, that it cannot be ſeparated, but by addition of ſome inflammable matter; the phlogiſton of which unites, at once, with the metallic earth, reducing this to the ſtate of metal, and with the combined air or acid, with which it forms the gas that is produced during the revival of metallic calxes?

Are not *metallic precipitates*, as well as calxes, combinations of acid and metallic earth? And is not alſo the revival of theſe precipitates effected by the combination of phlogiſton with the adhering acid, forming a gas; and with the metallic earth, forming the revived metal?

117. The *production of Air from the various factitious gaſes*, by water abſorbing part of theſe gaſes, deſerves well to be examined and aſcertained. If confirmed by further experiments, does it not ſhew the poſſibility of air being formed from other acids, beſides the nitrous; and that the properties of gaſes depend much on the kind of combination, as we have already conjectured?

118. We may eaſily perceive that many important queſtions remain to be aſcertained on the ſubject of this Treatiſe: And although we are highly indebted

debted to the sagacity and industry of those philosophers who have led us to our present state of knowledge, yet much more remains undiscovered to excite and recompense the zeal of future labourers in this fertile and still new field of science.

When we shall be able more fully to ascertain the constituent parts of the several gases, the proportions of these parts to each other, and the circumstances necessary to each mode of combination; we may then perhaps be enabled to discover the various compositions, decompositions and changes, which these fluids suffer in many natural operations. We may also perhaps be enabled to trace the same substance through a great variety of forms. Thus we may observe the oily concrete acid of vegetables undergoing its various changes through the different periods of vegetable life, from seed to maturity; till, by the vinous or other fermentations, or by fire, it be disengaged from the more fixed earthy matters, which were united with it, be more perfectly combined with phlogiston, and assume an elastic state. In this state, it may mix with the atmosphere, and conduce perhaps to some of the striking phenomena which happen there; or, be absorbed by the humid vapours floating in the air, and again conveyed by these vapours into the organs of vegetables; thus passing along in that perpetual circulation of matter, which makes the Proteus-like Face of Nature, an ever-varying, pleasing picture. Or, if we may be indulged a bolder imagination where our yet infant experience cannot reach; may not these fluids, while raised into their elastic state, undergo other changes? may they not be further decomposed and rarified into the most active

tive elements, and while they advance in this progression of subtilization, may they not acquire new properties and powers, unknown in dense matter? may they not then pervade all bodies, and become that highly elastic *ethereal medium*, which, as *Sir Isaac Newton* † conjectures, may be the immediate cause of *Cohesion*; of *Gravitation*; of *Electrical Attraction* and *Repulsion*; of the *Refraction*, *Reflexion*, *Inflexion*, and the *heat* of the *rays* of *Light*; of *Animal Motion* and of *Animal Sensation*?

† *Optics*, *Quer.* 19. 20. 21. 22. 23. 24. and *Principia Mathem.* §. *ultim.*

THE END.